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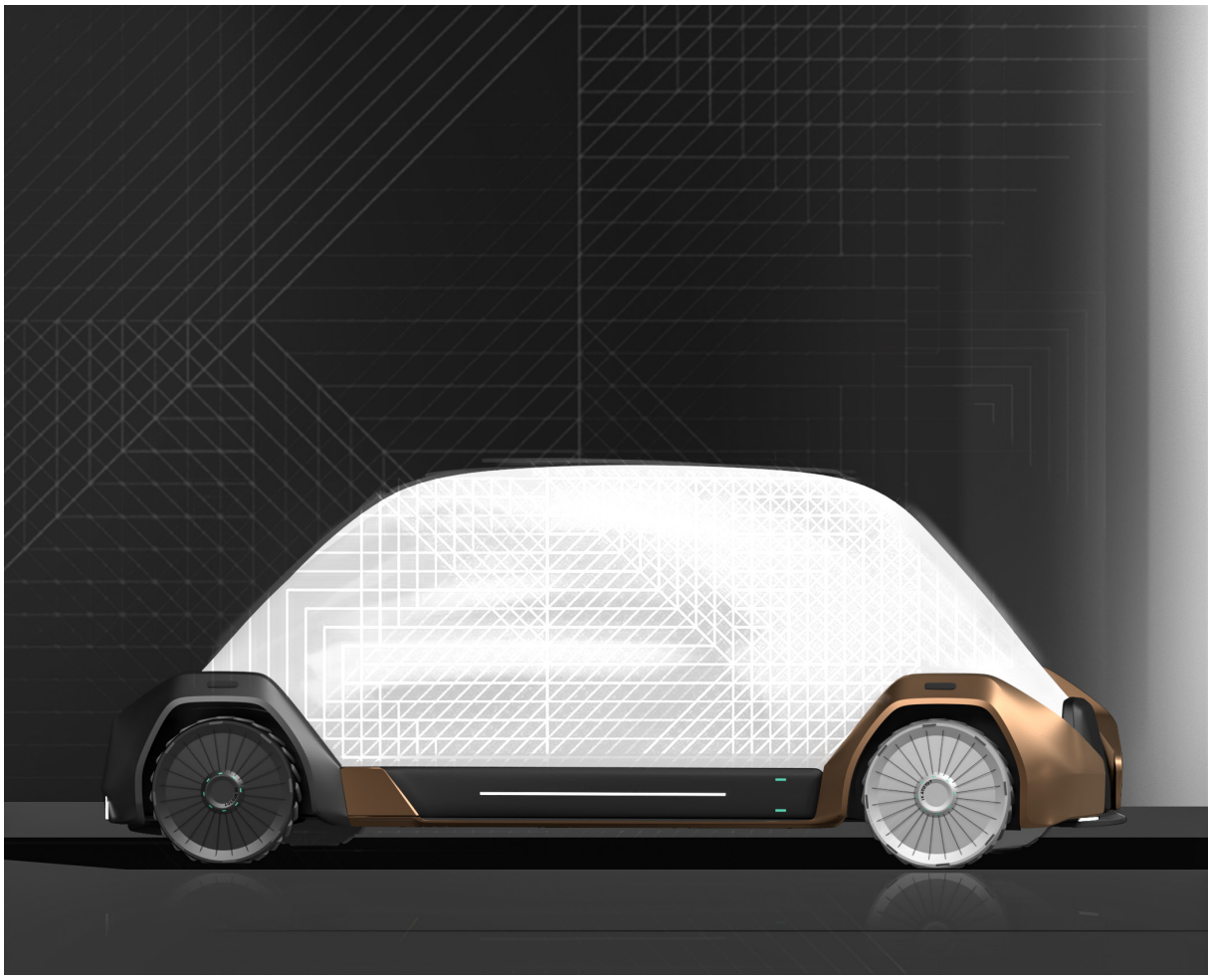

Concept study on urban object mobility

Master's thesis in Industrial Design Engineering

VIKTOR WESTBERG

CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2018

Department of Industrial and Materials Science
Division of Design & Human Factors

Master of Science Thesis

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Viktor Westberg

Abstract

Urban mobility as we know it is transforming. New types of ownership, services and completely new products are introduced. With the new technology, the purpose of the vehicle is changing.The future car is shaped as a space for social time, relax or work. Cars become smaller and lighter to fit in an urban environment and to be more energy efficient. What consequences will this have for the transport of objects, the second functional purpose of today's cars?

This project is a concept study carried out in collaboration with Design Center of Toyota Material Handling Europe. The project aim is to interpret and challenge the definition of a future product of Toyota, to inspire discussions about the future of mobility, logistics and the role of autonomous products in urban areas.

The project applies an explorative design process, structured around three main phases where each phase results in a number of insights to continually refine the focus of the study towards a final concept. The *Identifying* phase search for an initial framework for the study by defining a future vision related to an analysis of Toyota of today. The second phase *explorative* defines a user scenario and search for a direction for of a future concept within the initial scope to explore an alternative role of Toyota Material Handling in the future vision. The third phase *Refining* defines a final design concept that manifest the key insights of the project in a concept proposal for Toyota Material Handling.

The final result manifests the authors interpretation of the company in relation to a future scenario created. The concept is an autonomous product that can flexibly adapt to minimize negative impact on context when empty. The flexible material integrates kinetic properties in the surface with no solid components which allow the concept to be shaped by the objects it contain during use. This provides a natural variation of each product, in order to consider the contextual effects of repetition when products are used in systems.

The concept explores how future technology can be applied to allow an alternative direction for Toyota to meet future requirements of urban logistics and object mobility. The insights from this project can be used as inspiration and initiation of discussions related to the future of mobility for humans and objects and the role of logistics in urban areas.

Table of content

Introduction

The introduction of the report present the project background, aim, objectives, demarcations, project process and report structure.

Background

Without technology we move from A to B by walking or running. To move objects we carry them with us while walking. With industrialisation we could develop cars that we have to drive from point A to B. To move objects we take them with us when driving, inside the car, on the roof etc. We even developed trailers and other products to carry even more stuff with us. With the introduction of autonomous technology, we get access shaped to provide a service of effortless and efficient travel from A to B. This will introduce a major change in how we define human mobility. Though, what does this mean for the mobility of objects?

This project is carried out in collaboration with the Design Center of Toyota Material Handling Europe (TMHE). Being a part of the global Toyota Industries corporation, TMHE develop and produce products and systems for efficiency in material handling operations as an essential link in the logistics process of a wide selection of businesses. A company always have to question its own role and purpose in relation to the world they exist in. For a company developing and producing products, the definition of the business is always to fulfill a need. If the products produced today are acting as the definition of the company, the business will not be able to define its role as the context around are progressing.

The world are in constant flux. By conducting a concept study, a future scenario can be created in which the definition of the company can be explored and exposed to alternative definitions. By interpreting Toyota as a global cooperation, with focus on material handling, this project explore alternative directions of how the company could be defined in the future and applied to areas not previously explored by the company.

Aim

This project interpret and challenge the definition of a future product of Toyota. The result aim to inspire discussions about the future definition of mobility, logistics and the role of autonomous products in urban areas.

Objectives

This project explore future alternative applications of TMHE knowledge and expertise. The objective of the project can be divided into two main parts. The first is to identify a future application of TMHE expertise. By conducting research and analysis of trends in society and industry, a scenario of the future is created, in which the role of TMHE can be explored. Within this future scenario, a need will be identified which corresponds to a possible business opportunity not previously explored by Toyota Material Handling Europe.

The second part of the objectives is to design a concept solution that elaborate on an alternative direction for future TMHE products and how TMHE can contribute to meet future challenges of handling objects in society.

As part of the project objectives, the following assignments need to be considered and answered:

> Based on research, create an inspiring urban vision for Europe beyond 2035, in which the role of TMHE is challenged and explored.

> Explore the role of Toyota Material Handling in urban citizens ability to transport objects.

> Create a concept proposal for TMHE to explore possible application of future technology.

> Explore the relation and interaction between humans, context and autonomous TMHE products.

Demarcations

The final result are likely to be part of a service, though the project focus is to design the product/vehicle.

Project will focus on material transport from A to B when human and object does not have to travel the same route/ the same time or when only objects need to be transported. The product will exclusively focus transport of material.

The result will be on a conceptual level and will not include mechanical construction, technical details and detailed manufacturing issues.

Project process

It is not possible to make accurate predictions of the future. Though, based on research and facts, scenarios can be created that allow a designer to create a context in which concepts can be explored. The goal of the outcome is not to define the optimal solution of a specified problem. Instead the outcome should be viewed as an visualisation of one possible future. A tangible, yet visionary concept that inspire ideas, discussions and perspectives.

This project have been executed using an exploratory design approach, structured around three main phases called *Identifying, Exploring* and *Defining* (*image A*). Each phase results in a number of insights to continually refine the focus of the study towards a final concept.

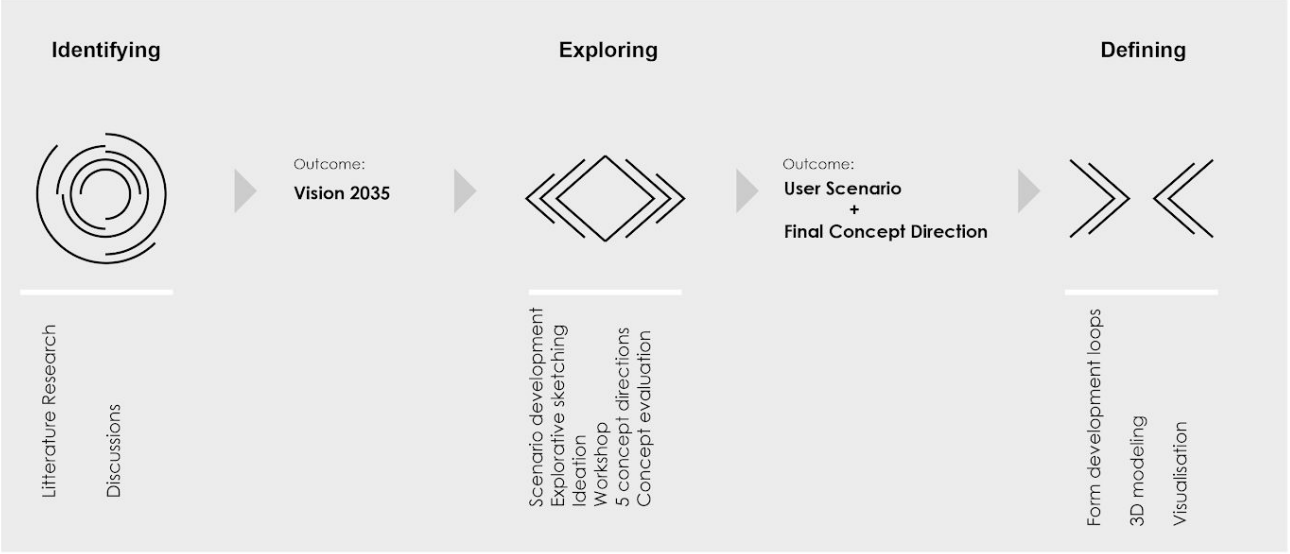


Image A. Illustration of project process.

The *Identifying* phase search for an initial framework for the study by defining a future vision related to an analysis of Toyota of today. The second phase *Exploring* defines a user scenario and search for a direction for of a future concept within the initial scope to explore an alternative role of Toyota Material Handling in the future vision. The third phase *Defining* defines a final design concept and form that manifest the key insights of the project in a concept proposal for Toyota Material Handling.

Report structure

This report is a documentation of the process, aiming to provide an overview of the exploratory process and approach used in this concept study. The project report is divided into six chapters (*image B*). Each chapter follows a structure of a brief introduction, objective and a description of the method and approach used as well as an explanation of how each chapter is structured. This is followed by the result that contains findings and insights. The result is followed by conclusions which highlight the main aspects of each chapter that are brought as input for the next chapter.

The first chapter *Research* describes the research that results in identification of an initial scope for the concept study. The second chapter, *Scenario,* identify and elaborate on a user scenario and user needs. This in order to refine the focus for the following concept exploration. The third and fourth chapter describes the conceptualization process towards the final concept. The third chapter called *Explore,* describes the process of exploring alternative concept directions. The outcome of the first part is a refined design brief and selected direction for the final concept. The fourth is called *Define* and describes the form development process of defining the form and function of the final concept proposal. The fifth chapter, *Final result,* is a presentation of the final concept. In addition, a final sixth chapter contains discussion and concluding remarks of the project, process and result.

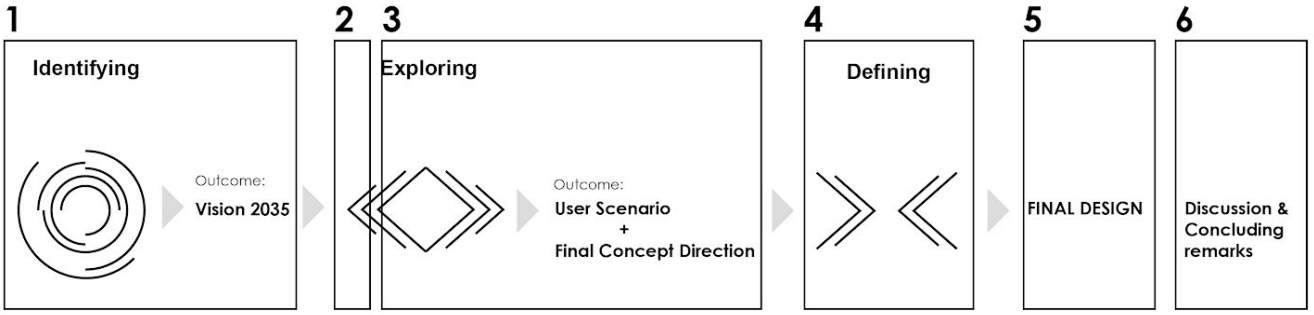


Image B. Illustration of report chapters in relation to project process.

I.Research

The first chapter describes the research and analysis to identify an initial scope for the concept study.

Research objective

The initial research chapter aims to obtain an overview and understanding of Toyota Material Handling Europe, part of Toyota Industries Co, as well as global trends in society related to the future of logistics, material handling and mobility. With understanding of the company and social trends, future needs and opportunities can be identified. This will create the foundation of which a concept study is conducted to explore alternative directions and application of the expertise and business offer for the future of Toyota Material Handling.

Methods and approach *Research*

The exploratory research phase consists of information obtained from several sources. The findings from the research phase are divided into three perspectives, *Toyota Material Handling*, *Logistics industry trends* and *Social trends*. Each perspective resulted in conclusions that were used as input for the following part to gradually identify an initial direction.

Research of the company was conducted with a basis in the products offered today. An analysis was conducted based on insights from a literature study regarding the products, a tour at the manufacturing facility and mapping of the products according to various properties. To analyse the visual form entity and elements, an analysis of existing products was carried out inspired by the *Form syntactics (Warell, 2001)* where the form is analysed in different levels. For the form analysis in this project, Images of existing products were collected. These images were formed into groups where similarities was found. With the images as a basis, the author started sketching on variations inspired by the images of each group, with the aim of developing an understanding of the form elements and how they can be used. This resulted in a number of form elements that could be used as inspiration in later form development process, described in chapter III and IV.

Logistics industry trends was researched through literature study of concepts and existing products. Products considered relevant to the project scope was mapped in relation to relevant aspects to obtain an overview and identify possible business opportunities. Societal trends was researched through an exploratory literature study during the process of defining the direction for the concept. In addition, discussions with professionals with various perspective related to the research was held in order to gain further insights.

The insights from various areas were finally combined in order to construct a vision of the future which highlights selected aspects relevant to the project. This vision was the initial outline and definition of the project focus.

How to read chapter I

The following sections present findings, insights and conclusions for each of the three perspectives. *Findings* present the main facts gathered from the research. *Insights* elaborate

on the authors analysis of the findings. The conclusion of one perspective should be viewed as input for the following to consecutively define an initial focus of the project.

1.1 Result Toyota

The project is carried out in collaboration with Toyota Material Handling Europe. Therefor the initial research aimed to provide an overview and definition of the company. The findings from analysis of the company is divided in four sections, answering the questions *What, How, Where* and *Who.*

1.1.1 Findings Toyota

Toyota Material Handling Europe (TMHE) is located in Mjölby, Sweden. In year 2000 the Toyota industries acquired BT to become the world's largest producer of products for material handling (Toyota, 2018).

What

Toyota is a global and diverse company, working in a number of businesses. The global vision of the company for the future is to *"contribute to a comfortable society and enrich lifestyles"*. Being part of the global Toyota concerne, TMHE focuses on a number of businesses with the shared purpose of handle the movement of objects within a defined context through a number of different products (*image 1A*). The mission for TMHE is to *"Bring exceptional efficiency to material handling operations".*

Image 1A Example of existing products in TMHE product range (Toyota Material Handling, 2018)

How

TMHE produces a number of different products for material handling. The company might mainly be identified by the iconic products such as the hand pallet lifter or forklifts, though TMHE offers a number of different products. To offer products for efficient material handling for a variety of demanding contexts, TMEH today sell products grouped in four different categories named *Order picking, Horizontal transport, Stacking, Loading & Unloading.*

The products range from manual to fully automated. Often, several products are used together to make up a material handling system within the context. By mapping out the products in relation to a number of properties, an overview of the main properties can be obtained (*image 1B*).

Image 1B Mapping of existing products in relation to various properties.

The products handle a limited distance transport of object. The products either handle the pick-up or exclusively focus on the horizontal transport to destination where humans unload the objects. The core values of TMHE products is defined by the company to be *Safety, Durability, Productivity, Driveability* and *Simplicity.*

Where

The products operate in a diverse variety of contexts (*image 1C*). Physically closed or open, indoor or outdoor. Products are today also present in an open, public context, for example in the process of delivery to shops and business within cities. Here the products operate in an area which is not physically enclosed. TMHE also offer product ranges specialized for specific context with challenging conditions, to meet demanding contextual criterias.

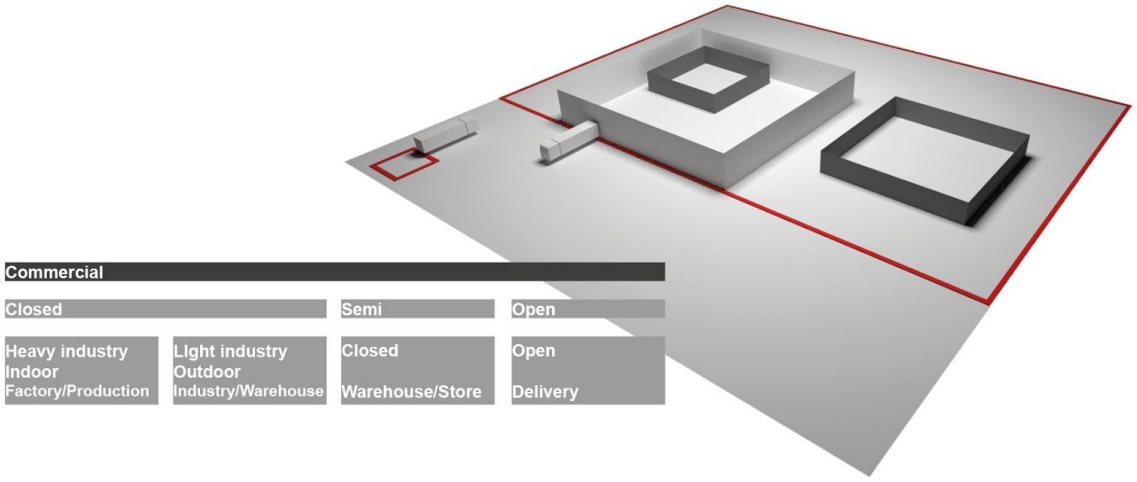


Image 1C Illustration of closed and open contexts where products are used today.

Who

TMHE today retail their products to businesses, where the users are using the products in relation to their professional tasks. Either as an operator or using the products as a supportive tool in their work.

Toyota Form Analysis

Collections of images representing forms and details of existing products was formed into groups (*image 1D*).

Image 1D Collecting images of form elements of current TMHE products.

Inspired by these groups, the author could initiate a sketch phase where the forms were reproduced and explored to develop a further understanding of the forms and how they are used in existing products (*image 1E*).

Image 1E Sketches and variations based on groups of images to develop an understanding of various form features.

The insights obtained was used to formulate a summary of the form analysis of Toyota Material Handling. Solid and dense forms created by large, uninterrupted surfaces and defined chamfer and bevels. An uplifting relation between the dominant and subdominant forms. The products express strength, control and robustness. The products have a defined direction and horizontal alignment of subordinated features along the primary axis of the vehicle when driving. The direction is often defined by the use of color in addition to a disruptive vertical form. THe colors used are one large orange field, often placed asymmetrical and combined with two versions of dark green. The key features are often placed asymmetrical, towards one end of the primary axis.

1.1.2 Insights Toyota

TMHE products can be defined by a number of main properties. The products are both specialized and diverse in handling a variety of objects within a specific and demanding context. The tasks are handled with maximized efficiency in a system created by several individual products working together. Each product contribute with high capacity while maintaining excellent navigation within the limited space the contexts require.

Toyota Material Handling has, as being a part of the Toyota Industries Corporation, an important function in contributing to a global society, as logistics is a central function in a progressive society.

By analysing the products from an historical perspective and by observing technological progress, a conclusion can be made by the author. The technology that TMHE are developing is causing an evolution towards a separation between humans and the products. The products are due to technological progress allowed to work more and more independently, an inevitable progression. Automation of material handling and distribution is highly beneficial within contexts such as the warehouse or manufacturing. Though, the same technology also enable new products, in completely new applications.

From conclusions made from the product offer, overall mission and opportunities emerging from technological progress, the author sees an opportunity to explore a future where the interaction between humans and TMHE products are enhanced to reach the global vision of contribute to the comfortable society.

1.1.3 Conclusions Toyota

The final concept should relate to the main properties of TMHE as identified by the author to be *Strength, Efficiency, Flexibility, Driveability/Navigation, Safety and Contextual adaptation.*

While the company today focus on products exclusively for professional use, this concept will explore applications directed towards a physical interaction between the products and private users. Thereby the decision was made to initially focus on an open context, taking a more societal approach inspired by the company's global vision.

1.2 Result Logistics Industry Trends

Based on the conclusions to focus on an urban context, research was conducted with the perspective of industry trends related to the business of Toyota Material Handling

1.2.1 Findings Logistics Industry Trends

The logistics system is today mainly created for handling large volumes with few nodes (P.O. Arnäs, 2017). Though, with new consumer behaviours, the industry needs to adapt to a reality of a rapid flow with increasing number of nodes. Several products have been introduced to the market or presented as concepts, to explore alternative systems for urban logistics and object mobility, with examples from Stockholm, Gothenburg and Frankfurt below.

Image 1F Älskade Stad, Stockholm (Älskadestad, 2018)

Image 1G Stadsleveranser, Gothenburg (Yimbys, 2013)

Image 1H Velove + DHL, Frankfurt (Velove, 2015)

A different approach to meet the new requirements would be to create completely new channels. Amazon as one example have filed several patents of new, innovative channels of urban distribution and logistics (BBC, 2016) (*image 1I*).

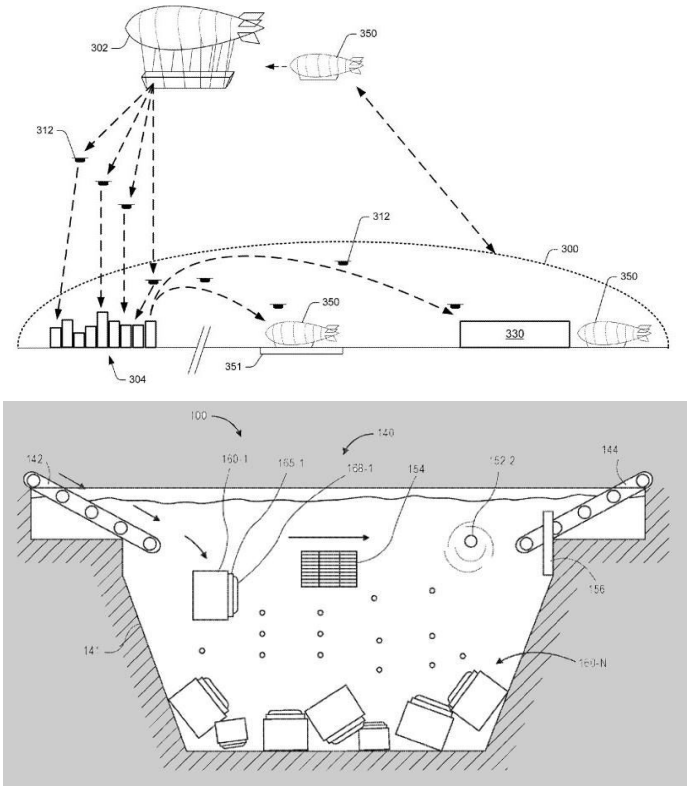


Image 1I Patents of urban delivery systems, Amazon (The Verge, 2016)

E commerce and Logistics

The market follow the people. With the urbanisation the retail moved in to the city. Now people are online, so is the retail market. The change from physical to digital consumption have a major impact on the logistics systems and services, resulting in an industry currently experiencing substantial challenges, seen in the major difficulties the logistics industry have in keeping up with the market(Ehandel, 2017). Consumers are quickly adapting alternatives to physical shopping, both new retail channels as well as new business modells. Forecasts of the home delivery business expect as much as 80% of parcel deliveries will be carried out with drones or AGV (*'Autonomous Ground Vehicles'*) in the next decade (McKinsey, 2016). Future customers will expect individual options and flexibility available when required, yet remaining price sensitive(McKinsey, 2016). Several *last-mile-delivery* concepts have been exploring different ways of instant delivery of parcels and smaller objects to meet the demands of fast, efficient and direct deliveries in urban areas. According to McKinsey, seven different models can be identified within the trends from analysing todays startups and technology advancement:

- Todays model with delivery person
- Drones
- Crowdsourcing
- AGV
- Bike couriers

- Semi Autonomous GV
- Droids

Several industry scenarios envision the transport and logistics industry as one connected system where different actors are collaborating, appearing as on seamless system from a user perspective. Companies will be part of a larger system which can adapt to the needs of the individuals in an efficient way.

1.2.2 Insights Logistics Industry Trends

By analysing existing concepts and products on the market, two main approaches have been identified of how to meet the future challenges of urban logistics. Products that adapt to the contextual requirements, or products and systems that define a new channel of moving objects within a urban context.

By mapping out a selection of concepts and products on the market, two main properties define the focus of products available (*image 1J*). Efficiency with small air- or ground drones or focus on capacity with products and machines for industry use. The author identified an area in between the previously mentioned trends where few previous concepts have focused, marked grey at image 1J. A product that combines the properties of an efficient transport in urban areas with increased capacity. This area also matches the properties of TMHE product which are flexible, efficient and versatile in handling large products in complex systems, making it a relevant business opportunity for TMHE for further exploration within this project.

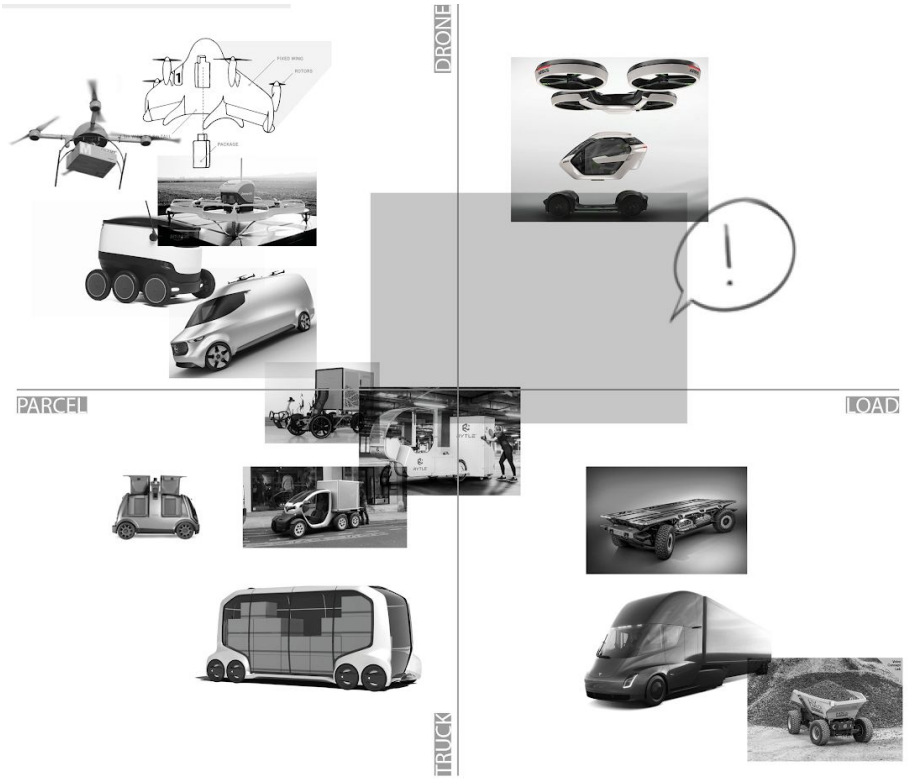


Image 1J Mapping of existing concepts and products with the identified focus area marked with a grey box.

1.2.3 Conclusions Logistics Industry Trends

The concept should adapt to the existing contextual requirements and infrastructure of the future city. It should provide efficient mobility with a large capacity. These are properties that correspond to the key properties identified from analysis of TMHE and position the concept to target the business opportunity identified on the market.

1.3 Result Societal Trends

To identify a future need, understanding of society is required. A correct prediction of the future can not be made, though by analysing research and trends, a vision can be created which highlight a selection of aspects of relevance. Research of global trends in society and industry aims to identify an alternative business area of TMHE, in which the interaction between the products and humans needed.

1.3.1 Findings Societal Trends

Urbanisation

The world becomes increasingly urban. In europe, just over 80% of the population is projected to live in urban areas by 2050 (Eurostat, 2016). The rapid urbanisation will have major effect on existing cities. So called ‘megacites’, which all exceeds 10 million residents, is expected in UK, France, Russia and Germany, either by expansion of current cities or by several cities being connected (GlobalPETS, 2017). Though the urbanisation will affect all urban areas. Every major city in Sweden have already experienced an increased density in city centers.(SvD, 2014). The increase is not explicitly focused to the central parts, with peri-urban areas grows at a rate four times higher (Openspace, 2015). The increase of population in urban areas require cities to adapt to meet the increased number of citizens.

As urban areas develop, they will expand in all directions, including vertical (Nature, 2013). More people in a limited space challenge cities to use the available space in an efficient way, which drives innovative solutions. One example is urban *vertical farming,* as a way to provide efficient food production with minimal use of energy, area and transport(BBC*, 2017)(*Plantagon*, 2017*). Infrastructure and logistics is a major competitor for space in urban areas. Cities of today are to a large extent based around a system of cars, roads and parking spaces. (What the street !?, 2017). Though, private cars are have and average use rate about 3%, which leaves it parked the rest of the time(RAC Foundation, 2012). With increased competition of space from increased urbanisation, cities can no longer be shaped for inefficient systems where resources are left unused and more land area is assigned parked vehicles than used (Chester, Fraser, Matute, Flower, Pendyala, 2015).

Pollution

Air pollution is known to be harmful for human health and the environment. Despite a positive development in terms of decreasing figures for the main air pollutants, many european citizens still live in areas where air quality exceed target values(European Environment Agency, 2017). The issue is focused mainly to urban areas, where standards for air quality are exceeded regularly for a significant part of the population (Greenfacts, 2018).

Transport is a major contributor to the pollution and answers for more than half the CO2 emission in cities like Oslo, of which as much as 39% comes from private cars. Private cars is the undisputed leader in terms of emission, in relation to taxi and public transport that combined only reaches 6%. (“Vehicles in use Europe”, 2017).

Cities taking action

The system of today's urban mobility is not suitable for the challenges that face cities in the future. An increased density and the air quality are factors that will require a new approach of urban structures and functionality. There are today a lower rate of car ownership among urban citizens compared to rural population.(Trafikverket, 2014) To restore the quality of air and life for the people in urban areas, several cities are taking actions towards a sustainable future for dwellers as well as the environment.

Barcelona superblocks

In 2003, the city of Barcelona began to initiate testing of the 'superblocks'. City blocks are combined into zones in which traffic is restricted. Within the zones traffic is limited and speed limits of 10 km/h. The superblocks aims to make vehicles and traffic to adapt to humans, not the other way around. ("Superblocks to the rescue", 2016)

Copenhagen bike highways

Extensive expansion of infrastructure for bikes. Plans have been initiated to expand the bike highway grid to 26 routes to expand the cover of the alternative infrastructure. Have resulted in above 40% of today's business trips within city are done with bike. By making the better alternative more accessible and convenient, the behaviour have changed dramatically. (Copenhagenize, 2017)

Oslo car ban

Oslo have ambitious plans to reduce emission of co2 with 95% by 2030. To reach this goal, the city have presented a plan which gained public attention. By 2019, a ban on parking spaces aims to reduce the use of private cars within the city center. This is a first step that will be followed by a country-wide ban on combustion engines by 2025. Instead the city focus on expand heavy investment in public transport system and alternative modes of transport. (Business Insider, 2018)

Several other cities around the world moving the same direction. A long list of cities with outspoken plans can be conducted. Madrid, Paris, London, Helsinki Hamburg, Chengdu, Mexico City, Bogotá among others all have plans to reach car free areas(Business Insider, 2018). Planning of urban areas and systems is essential to reach a balanced and sustainable future, with efficient use of space, resources and nature.

New era of mobility

The next major change in mobility and transport of the future is not only driven by the urban context. Also the (automotive) industry is a leading force in redefining the journey between A and B by technological progress. Major disruptive technology emerge that will lead the world into a new era. A vehicle is today according to Oxford dictionary defined as *'a thing that is used for transporting people or goods from one place to another, such as a car or lorry/truck'*. This definition might still be valid for the future, yet have a completely new meaning for the people.

For private users, the vehicle is identified as a car that, together with additional products like trailer, rooftop box etc are used to move people or objects from A to B. In 2015, 252 million passenger cars were registered in the european union(ACEA, 2017). The cars of today are mainly run on petrol or diesel, with only a fraction driven by alternative fuels, according to *ACEA*. Though vehicles and mobility industry is likely be on the verge of a new era.

Several factors are about to change the automotive industry. The vehicle of the future can be defined using five main factors: *electrified*, *autonomous*, *shared*, *connected* and *updated* (PwC, 2017). New technology will allow the vehicles and their purpose to be be completely redefined.

Fully electric vehicles are becoming increasingly familiar and products like BMW i3, Tesla, Nissan Leaf and Renault Zoe are well established on the market. The drive range may still be an issue for longer drives but are constantly improved with battery technology and expansion of charging station networks. Electric vehicles today comes without trailer hitch, though the industry are positive towards the future for electric vehicles also for heavier transports with exempel of Tesla Semi, Einride and Volvo CE HX.

Today about 1% of miles traveled are done using sharing services. This figure may exceed 10% already in the second half of 2020 (PwC, 2017). Other predictions expect ´numbers far above 50% made by various business models referred to as *Taas* (*'Transport-as-a-service'*) instead of privately owned cars. Since the first keyless system in 1993 opened up for car sharing the industry have expanded and today on-demand and car-sharing services are increasing more than ever (PwC, 2014). Alternative mobility services are emerging everywhere, both from traditional automotive industry (Ex Moovel (*Mercedes*), Sunfleet (*Volvo*), Maven (*GM*) and MOIA (*VW*)) or major tech companies buying in on existing services (Toyota investing in Uber, VW in Gett and GM in Lyft). Data and technology companies like Google, Apple and Alibaba as well as the stream of digital start-ups focusing on technological development.

The autonomous technology will have a significant effect on developing advantages with mobility services, by allowing more flexibility and efficiency to create a sustainable traffic system. This means future car is not only a product, but an experience of moving between A and B. The same is likely to be said for all types of vehicles, including those who serves a more practical purpose. Vehicles are becoming a service rather than a physical object. From a technological perspective, a new definition of mobility can within a near future become a reality.

Alternative transportation modes

Alternative modes of transport is increasing, of small personal vehicles for urban transport. Services with shared vehicles used on demand are today a well established system provided in several cities, with common examples like 'Styr&Ställ'. The bike have with the advancements of battery technology and small engines emerged as a common alternative for urban commuters (Stockholm Handelskammare, 2016). Similar technology have resulted in a range of vehicles that cover the span from traditional bikes to driven vehicles. Also light

and compact products to accommodate transport of human are increasing on the market, such as *Toyota i-ROAD, Renault Twizy* and *Opel RAK*. These all have in common the properties of being compact and electric vehicles for efficient urban mobility.

Users

The attitude and behaviour of users is in constant movement. Each generation grows up in a world, different to what it once were. The new generation, referred to as *Generation Z* (Wikipedia, 2018), is a generation growing up being constantly connected and interacting with technology.

From a technological perspective, the urban society will in the next decade be ready to evolve from *possess* to *access*. Though such evolution will also require the acceptance from users and adaptation of a new behaviours. Habits may be a strong counter force against a transition from owning to sharing (S. Harms, 2003). Though, new habits will also come with a new generation. *Millennials* and *generation Z* has grown up with access to information and technology as part of their everyday life, mainly referring to the smartphone. The new generations expect everything to be accessible through the smartphone, and it is today used for everything from social interaction to banking.

Car ownership are decreasing among young adults in large markets like Germany, in favour for alternative modes of transport (Kuhnimhof, Buehler, Wirtz, Kalinowska, 2012). The next generation vehicles will create a new type of interaction. Electrified, autonomous and connected products will require development of interfaces and communication, towards other vehicles as well as with humans. This is crucial not to constrain the implementation of the technology on the market (PwC, 2014). In the three major cities of Sweden, the number of cars per capita is significantly lower than the country's average. Several studies of user behaviour suggest that the new generations are more open towards alternative mobility models (PwC, 2016). Zero-car households are car-less not car-free, which means the major change lies in the ownership model rather than the product. (Brown, 2017). The major shift is yet to come, though user's attitude is changing with more efficient, convenient and cost effective alternatives emerging. Urban residents show a fading interest in owning cars, when other modes of transport appear as better alternatives (PwC, 2016).

Peer-to-peer

An alternative to buying new products from manufacturers is to buy, trade or rent from others. Used products have several benefits such as the environmental and financial. Two of the major peer-to-peer sales markets in sweden, Blocket and Tradera, are both growing continuously over the past years(Di, 2017) (Tradera, 2016).

Connectivity of private people have already revolutionised several industries, like AirBnB within travel and housing and Uber for taxi service. One main issue that may constrain a similar revolution for online shopping and peer-to-peer sales is the logistics system, especially for heavy and bulky objects. New challenges are introduced when moving from books and small parcels to object with increased dimensions, volume and weight. ("Scenario för e-handelns framtida tillväxt", 2012)

Owning
Even though new business models and connectivity will open up for alternatives access and consume products, humans will always develop emotional relations to objects (MariAnne Karlsson, 2017). People may make more conscious choices, though personal belongings will not completely be reduced within the timespan relevant to this project.

Visions
Major changes will happen in cities within the next decades, and urban areas need to adapt. To understand the challenges and opportunities of the future reality, research conclusions are used to create visions to explore and anticipate the future. This project is based on two main visions of the northern Europe region, the *Göteborg 2070* ("Göteborg 2070", 2015) and *Future cities dialogue* (Forum of the future, 2017).

Future cities dialogue: United kingdom, 2035. Presents a future where the autonomous technology have been implemented. Even though the system have not completely changed, major consequences have already had impact on people's everyday life. Groceries are delivered at the door during nighttime when the streets are empty, and during the day the streets once filled with parked and driving cars are now safe to be used by pedestrians. The reduction of parking spaces have allowed for several new public areas for citizens to spend their spare time. Citizens can get whatever they want, whenever they want it through efficient systems provided by private companies and government together. The use of big data allow the city to be dynamic and adapt itself to maximize efficiency.

Göteborg2070: Presents a future vision of the swedish west coast and the 'Öresund' region. The region is presented as a rich and diverse area where the individual is free to choose where to live and where to work. By providing several alternatives, all connected by a mobility system, the pressure on the city center is decreased. This makes room for social dynamic places for interaction. Our travel behaviour will change within a connected world. We will only travel if we want. The public transport have evolved into a network connecting the whole area. Several actors are connected to provide people with a seamless service that adapt to individual needs. The mobility service adapts to the individual needs and provide customised services. An efficient and customised system is possible due to the introduction of autonomous vehicles. Heavy transport and logistic systems are separated from the public room to eliminate barriers in the city. With more efficient use of vehicles the need for parking spaces are reduced within the city.

1.3.2 Insights Societal Trends

Based on the findings from the research, a vision was created by the author. This vision describes the author's view of a possible future of urban areas in northern europe, beyond 2035. This vision is a summary of a selection of key findings from the research that are relevant to the scope of the project.

VISION 2035

Urban areas will be more populated than ever before. Mobility is a key factor in reaching sustainable and efficient cities for dwellers, society and environment. People are conscious and aware of their possessions and consumption, and appreciate the convenience of customized services that suits the modern lifestyle of freedom. For the logistics industry, this means a more active role in society. The disruptive technological revolution will allow completely new vehicles and products. Though, the major change and benefits for individuals and society is not the properties of the physical product but rather the consequence that allow a new definition of how humans consume and access the fulfilment of needs, following the evolution from a *product* to a *system*.

Users

People value access over possess. Through the development of collective systems, we are able to fulfill needs by consuming services rather than objects, which enables a community with room for individual needs. In a world of shared economy, humans become more aware and conscious of possessions. Individuals strive for convenience, freedom to choose and be unique. In a world of material accessibility, people strive to express one's personality and individual character.

People are open and adapt to innovations and technology when beneficial in making everyday life convenient. Advanced technology is part of everyday life, yet is expected to be purposeful and user centered. Technology and systems are accepted to work invisible, yet humans want to maintain perceived control and not be excluded by technology.

City

Cities are becoming human centered. This affects priorities and decisions. Efficient use of space and resources for a sustainable urban life, both environmentally and emotional for citizens.

Cities are through new systems becoming more dynamic and adapt to individual and societal needs. The cities are diverse and functional to be sustainable and allow dwellers freedom and convenience. The city facilitates both urban and natural spaces to offer alternatives for all residents. The area consists of networks on different levels that connect people, both physically and digitally. Public and private actors together contribute in providing services to maintain a system that benefit the city and individuals.

Previous dividers of the urban areas such as infrastructure for freight transport have been separated to a grid. A human centered city center is designed for walking, small urban

transport and efficient commuting together with logistics and functional services that all adapt to suit the human centered cityscape. In a city shaped for humans, efficiency and technological evolution is not accepted to interfere or restrict the human experience. The city is a comfortable and inspiring environment.

Mobility
For private dwellers, the private vehicle is being replaced with mobility as service. Neither from a societal or individual perspective, a system based around privately owned vehicle is motivated from a financial, efficiency or convenience point of view. The functions of mobility for humans and objects is instead provided by various services and systems focusing on convenience and experience.

A mix of vehicles with large capacity for commuting and smaller, individual alternatives for flexible urban transport provide urban dwellers with alternative to fulfill individual needs. Autonomous technology are being more and more dominant and allow a new definition of efficient and convenient mobility.

Due to the changes in how we consume, the presence of logistics have evolved to have a more central role in society. Private citizens are regularly interacting with product part of logistics systems, handling a complete flow from groceries to recycling. Users expect a flexible service that adapt to individual needs to provide a convenient life, where people have the freedom to choose how to spend their time.

1.3.4 Conclusions Social Trends

The future vision created based on the insights describes an alternative future where logistics, mobility and society all are linked in a system around the human. The vision can be used as a manageable format to bring insights from the research phase into the conceptualization phase. The vision provides the project with a framework to allow an explorative process yet remain within the initial direction.

II.Scenario

Based on the research conclusions and vision, the second chapter describes the process of identify a scenario and user need to further refine the focus of the concept study.

Objective *Scenario*

This chapter aims to identify a user need within the future vision, related to the business offer of TMHE. The final outcome of the second chapter is a concept scenario and definition of the main requirements for the final concept to meet the requirements from the selected scenario and context.

Methods and approach *Scenario*

By analysing the vision created, consequences could be identified that creates a user need of the future. Based on this, existing solutions was identified and could be be analysed by mapping out each key step. The process of using the existing solution was broken down into steps relevant to the project scope. From this, pros and cons of each existing solution was identified and used as input for defining the focus of the concept to be developed in this project. The findings from analysis of existing solutions, in combination with findings from the research phase, was used to define a *concept scenario.* The *concept scenario* describes the user, needs and key steps of which this concept study was to focus on.

To further analyse important aspects to consider during the concept study, a *concept journey* was created, from the perspective of the concepts to be created within this project. The *concept journey* broke down the scenario in order to identify requirements and aspects to consider. The final conclusion is formulated as a list of aspects and properties the concept should relate to. The concept journey and requirements provided a refined definition of product scope as final input to the conceptualization following in chapter III and IV.

How to read chapter II

This chapter present the process of defining the concept scenario and requirements and is based on a progressive analysis process starting with the findings from chapter I. Each section provides insights essential to proceed to the section that follows.

2.1 Result *Scenario*

2.1.1 The need

The research suggests a future that implies major changes in the everyday lives of humans. Urban population, to which a vast majority will be counted, will live, consume, move and communicate in new ways. A future of mobility will no longer relies exclusively on personal vehicle. Based on the research, the authors hypothesis is that the personal car and the two practical functions of human and object mobility will be divided into separate systems.

While several factors are contributing in redefining urban mobility for humans, consequences emerge. As human mobility evolve into a system, a responding system is required to meet the second functional purpose of the private car, the transport of objects.

Humans develop emotional relations to objects. This means humans will always have an urge to possess objects meaningful to the individual. Thereby the ability to move possessions will still remain, also in a future of shared economy and services as alternative to product consumption. The need of transporting objects is irregular and not linked to self fulfillment or lifestyle, in relation to human mobility. It is a basic need, yet fulfillment of the need when occurring is essential for the everyday life of urban dwellers to be convenient.

Several concepts for light and small object transport in urban areas have been extensively explored in concepts, as well as human mobility which have widely been explored and implemented in products, concepts and business modells. Yet, the handling of larger have not been directly addressed and remain a major challenge for urban dwellers. Especially when private citizens ability to individually move objects within a city is limited as a consequence following the evolution of the private car system.

2.1.2 Existing alternatives

As the dominance of the private car as defined today will decrease, a number of alternative options to transport objects are still available. Two main scenarios have been analysed, rented truck/trailer and professional transport as a service (*image 2A*).

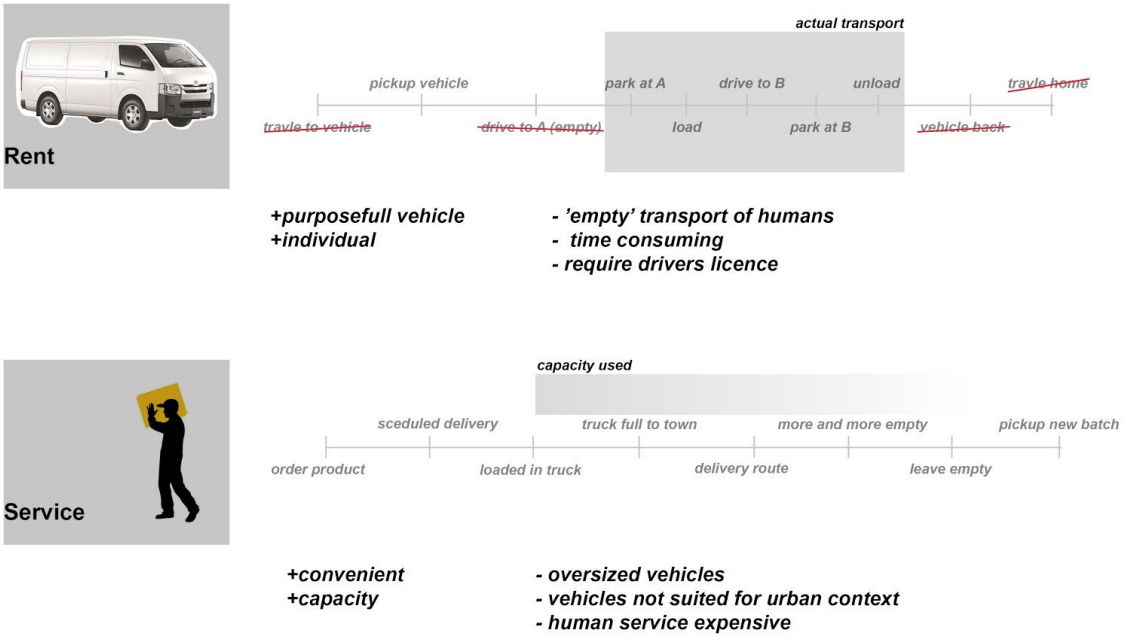


Image 2A Analysis of two existing solutions

Rent

Using a rented vehicle or trailer require user to first access the product at a physical pickup point. From here the vehicle is transported empty to the location of the objects to be moved. The user handle the loading and securing of the object before transporting the load. When arriving the user unload the cargo at final destination and the need is fulfilled, the vehicle has to be transported empty back to original location. After this the user needs to travel back home before the task is completed.

To rent a dedicated transport vehicle enables users with large capacity when needed. Though by analysing all steps required to fulfill the need, one can see that a majority of the transports are transport of the user, without any direct functional benefit for the task to move an object. 4 out of 5 in the scenario analysed are human transport secondary to the main transport. This result in high inefficiency in time and resources for user, as well as increase load in infrastructure, consequences in direct contradiction to the requirements identified in the conclusions from the research. The solution also require users to possess drivers licence, which are expected to decline among urban citizens followed by the emergence of autonomous alternatives.

Service

When using a service to transport an object, for example from a purchase online, the time for the transport is set by time of delivery, defined by the user or more often by a timespan offered by the delivery service provider. The object is normally loaded in a truck among other cargo with nearby destination. Effort is made maximize use of capacity in truck driving into the city. Along the route the density of the load naturally decreases while cargo is delivered. When route is completed, the truck leaves empty until arrival at destination for picking up new batch.

The truck provide large capacity and can combine several deliveries into one. Drawbacks from this is though that the full volume capacity of the vehicle can rarely be fully used. Despite this, the volume occupied by the vehicle is constant. This volume are not suited to fit the urban context and meet the criterias of minimal impact on the human centered city of the future. Lastly, a human operator offer some benefits and value to the service, though to a financial cost which arguably discard manned services as the only future solution.

Insights

The existing solutions analysed possess beneficial properties. Though they also involve aspects in direct contradiction to the vision. An alternative option is required to meet the requirements as defined in the vision. An option that allow a flexible and adaptable solution that handle users object transport efficiently and meet the criterias for an urban context of the future.

2.1.3 Concept scenario

The need to move objects within a city can be related to several causes. To further define a focus for the conceptualization, a scenario was selected that visualize the focus of the concept study. The selected scenario describes a peer-2-peer purchase of a sofa within a city (*image 2B*). The scenario was selected because it corresponds to the capacity relevant to the project and highlights a scenario that focus exclusively on mobility of objects, while still maintaining human interaction with the product at both A and B.

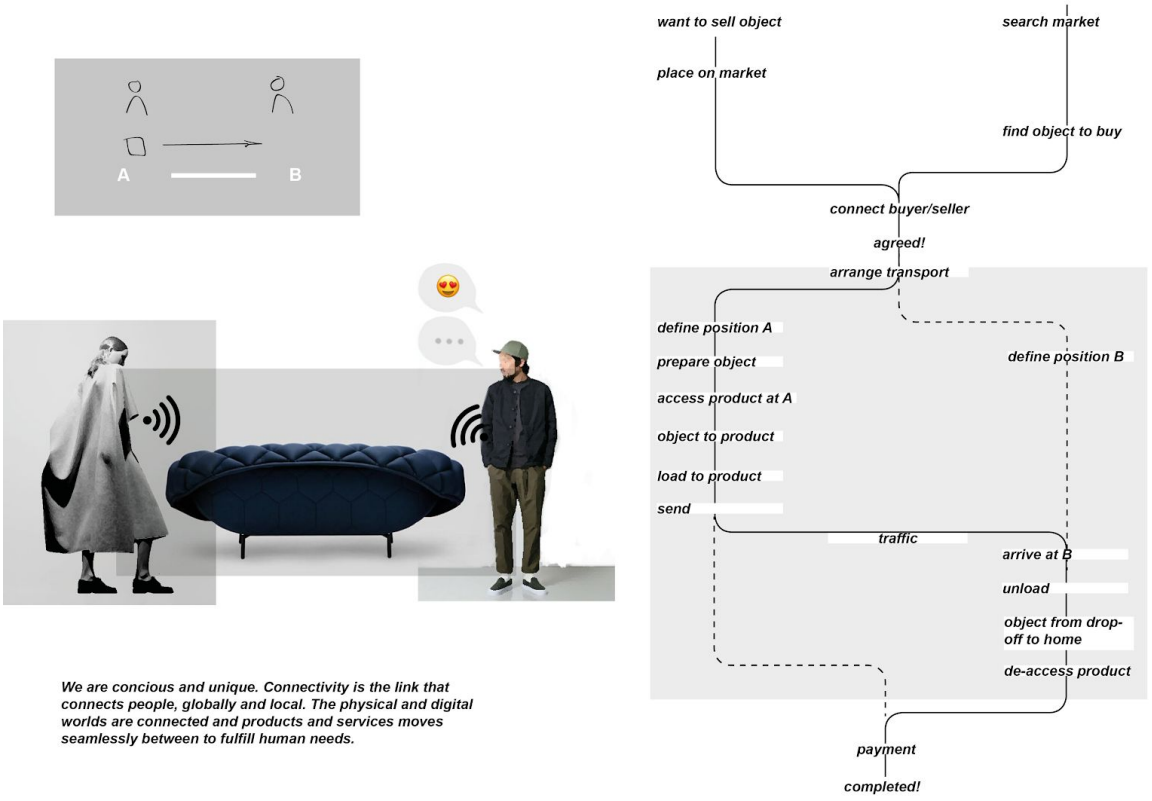


Image 2B Illustration of selected scenario

Why TMHE

The choice to explore the future of TMHE within an open, urban context is based on the need from a societal and user perspective that the author find related to the expertise and properties of TMHE products and business offer. The capacity, diversity in objects handled and complexity regarding limited space and systems of the urban context all have a relation to the challenges currently addressed in warehouses.

From the analysis of the industry, a more present and active role in society may be expected from the logistics industry. This highlights the relevance of TMHE to explore a role in an open context with direct interaction with private users. Market analysis highlight the business opportunity and user need, which yet not have been addressed by the industry. The problem define an area which tangents both automotive, transport and logistics industries. As part of Toyota Industries and the holistic approach to a society, TMHE have the knowledge and ability to fulfill this need in the future.

The current products of TMHE possess several properties that meets the requirements from the context and scenario. Though, a number of essential aspects are not considered. The solution have to be designed to meet the criterias of urban areas, regarding physical context and surface, yet more importantly the communication and interaction with users and context. Therefor, the concept will use existing TMHE products as inspiration, yet aim to define a new type of vehicle, shaped by the new context and purpose.

What capacity

The capacity for the concept was based on a combination of factors. It should first of all relate to the the selected user scenario and vision. Also it corresponds with existing solutions of today of personal car or trailer, that by their absence will contribute to the need of an alternative solution. Finally, the selected volume consider the market opportunity identified from analysis of current concepts and emerging innovations.

2.1.4 Concept journey

The concept scenario was elaborated to identify key steps and features for the concept by conducting a *concept journey*. The scenario was broken down into eleven key steps (*image 2C*) required to complete the task, highlighting key steps affecting the concept to be developed. By doing this, an overview of the concept requirements and key features could be identified. In addition, the mode of the product as well as type of interaction between user and the product could be specified as a way to label a set of properties during a specific part of the *concept journey*.

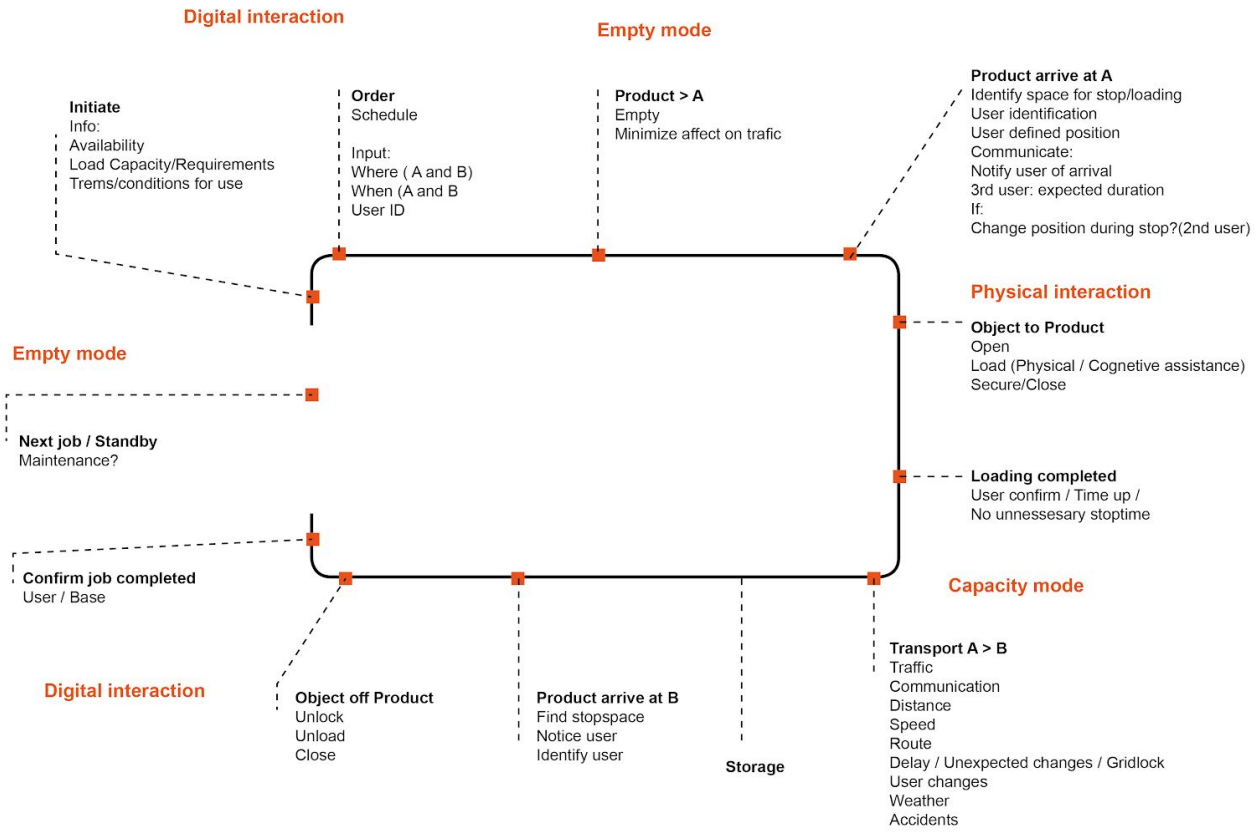
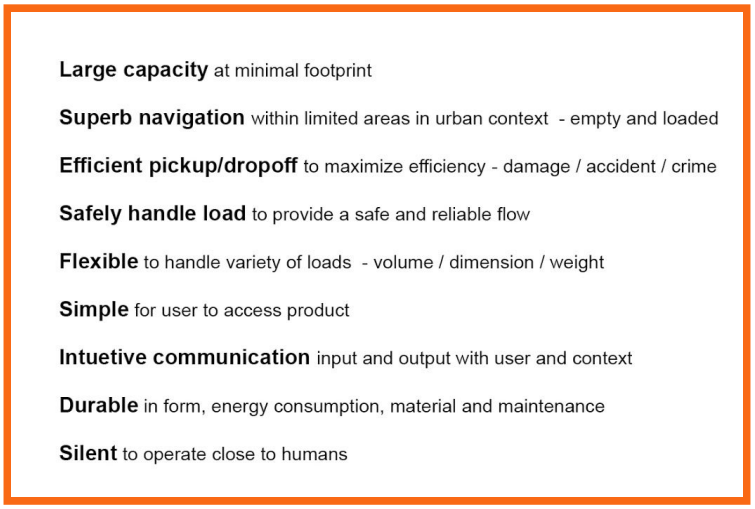


Image 2C Illustration of concept journey

2.1.5 Concept requirements

From the *Concept journey*, a number of requirements could be identified that corresponds to the properties of today's product offer from TMHE:



2.2 Conclusion *Scenario*

By defining and analysing the scenario, an outline of requirements concept was defined that highlight key aspects of the concept as input for further process. This provide a structured and well defined overview of the focus for the conceptualization phase.

III. Explore

With the concept scenario and requirements as input, this chapter describes the initial conceptualization phase with the process of exploring alternative directions. The outcome is a final concept direction

Objective *Explore*

This part aims to explore alternative solutions as answers on the challenges defined from the research and scenario phase. Sketch-driven approach to explore and identify questions and solutions for a future scenario and challenge the definition of a TMHE product. The explore phase aims to identify a number of concept directions, of which one is selected for further development.

Methods and approach *Explore*

Inspirational research was conducted to gain inspiration in initial search of directions. The visual media gathered was used as inspiration input for ideation phase. An extensive ideation phase was conducted based on sketching with various level of abstraction. First a high level of abstraction was held, referred to as exploratory sketching. Here the author was given complete freedom to explore, driven by input from inspirational research. Fragments and ideas was used as input for a second ideation phase, where ideas were combined and altered in the shape of conceptual products. The ideation phase was an iterative and intuitive process where the process itself was fuel for the process to continuously progress forward.

To gain additional perspectives to the ideation phase, a workshop was conducted in the format of a creative discussion. Three participants were invited, all industrial designers with experience from transport and product design. A brief summary and introduction of the background, context and scenario was given to each participant in advance of the workshop. A number of four issues or aspects were highlighted to be focus areas of the workshop. Each participant was assigned an issue of focus in advance of the workshop, with the purpose of having initial thoughts brought to the workshop by the participants. During the workshop, each task was discussed in group. Images that visualised the issue was provided, and participants were encouraged to use thumbnail sketches or words to document the ideas discussed. The outcome highlighted a number of aspects and contextual factors for the concept to consider.

From the explorative sketching and workshop, a final number of 5 concept directions were presented as resulting outcome. These were together exploring and highlighting a number of solutions and challenges relevant to the vision and defined user scenario, all having a relation to TMHE existing products. The directions each represent a different basic principle and are challenging different aspects of the focus and demarcations for the project.

The concepts were evaluated using a SWOT-analysis and measured towards the solution requirements. To include opinions from TMHE, the concepts were also presented and discussed at a presentation for TMHE. This feedback was also included in the final decision for a direction to proceed.

How to read chapter III *Explore*

The result of the first part describes the explorative process from initial ideation to defining the final direction. Each section ends with key findings that highlight what each section contributed, as input for the section that follows. The first part ends with a conclusion that summarise final concept direction and provides the foundation on which chapter IV *Define* is based. Relevant methods and approach are described in the beginning for this chapter.

3.1 Result *Explore*

3.1.1 Inspirational research

Inspirational research resulted in a visual representation of existing technical solutions and constructions (*image 3A*). Focus was on products and vehicles that had no or low direct relation to the current products of TMHE.

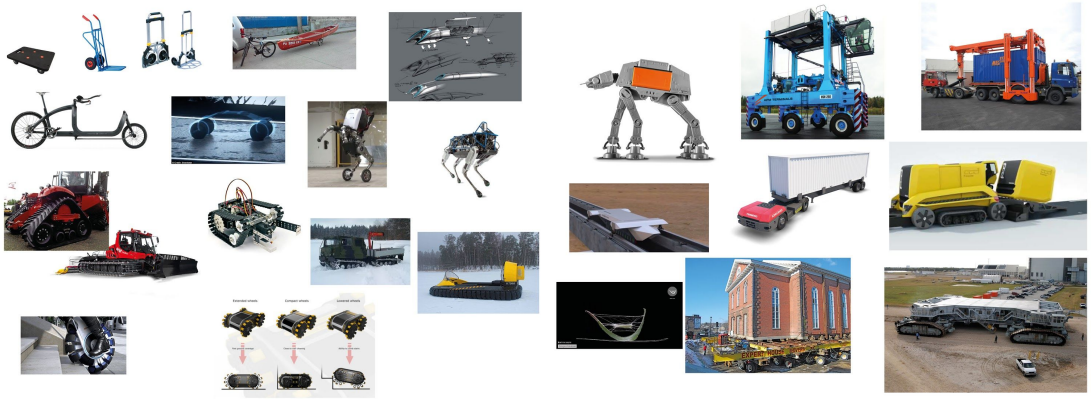


Image 3A Examples of images demonstrating the diversity of the inspirational research.

Key findings from inspirational research
Technology, principles and form to use as input for ideation. The result gave knowledge of unconventional technical solutions for horizontal transport.

3.1.2 Ideation phase I - high abstraction

This phase Initially driven by input from *inspirational research*. By experimenting with various techniques the ideation phase could maintain an open relation to the ideas, see example below. The outcome for this process was specific ideas as much as inspiration for further ideation (*image 3B*).

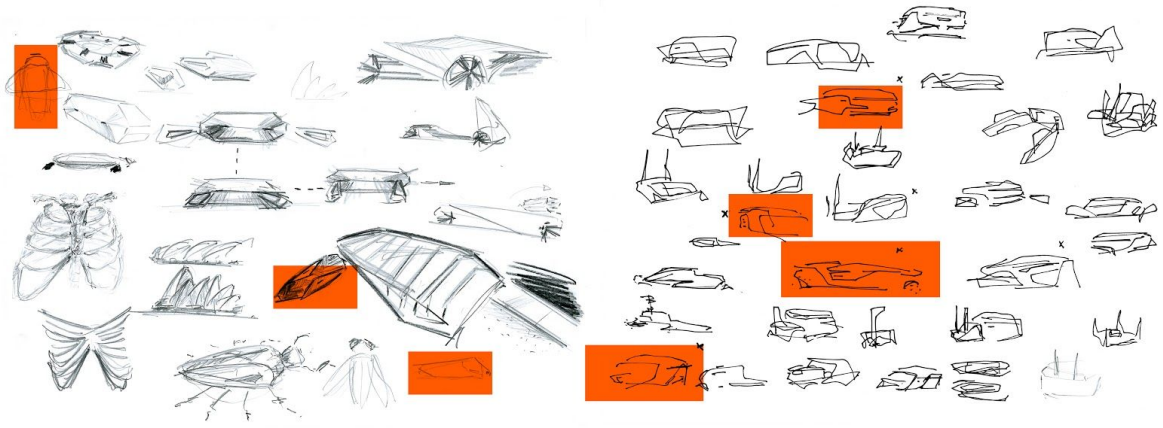


Image 3B Explorative sketches from the ideation phase I.

Key findings from ideation phase I
A number of principles inspired by nature on kinetic structures was found and explored.

Several form fragments were challenging features and form language of TMHE and Toyota.

3.1.3 Ideation phase II - concept sketching

With the input form the first ideation phase, the second ideation phase focused on concept sketching and translate the initial ideas into concept products.

Concept sketches (analog)
A number of ideation sessions were conducted whare solutions principles and form was explored through basic hand sketches. The outcome was solutions of specific aspects or concept products for further development (*image 3C*).

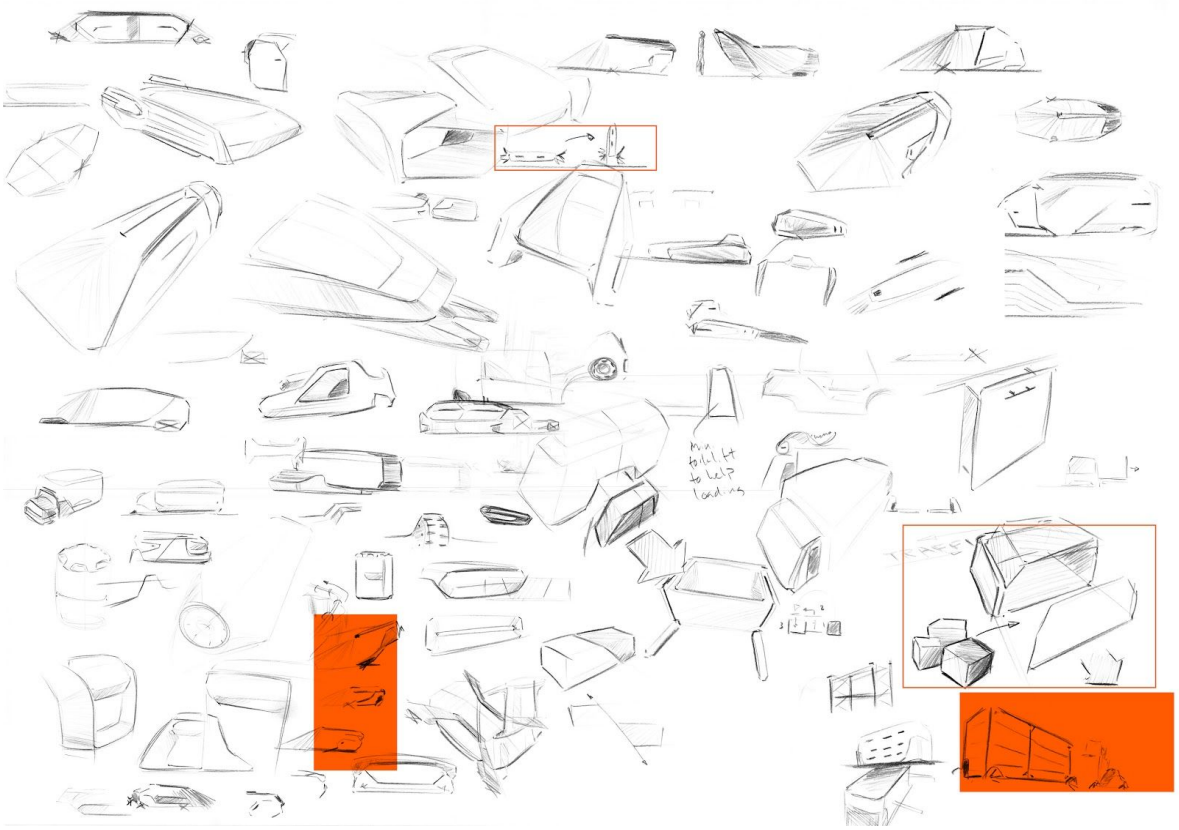


Image 3C Example of various sketches from the analog concept sessions.

Key findings from concept sketches (analog)
A number of solution principles was identified of specific aspects of the products. The process explored ideas of how to open and close the product and the overall orientation and layout to obtain a functional form. These solutions could be used as building blocks and input to generate a number of concept ideas during the following ideation process.

Concept sketches (digital)

With initial ideation outcome as input, further ideation was conducted using digital tools. This enabled rapid iterations which elaborated on initial ideas (*image 3D*). Also form elements identified in the TMHE form analysis was used as inspiration.

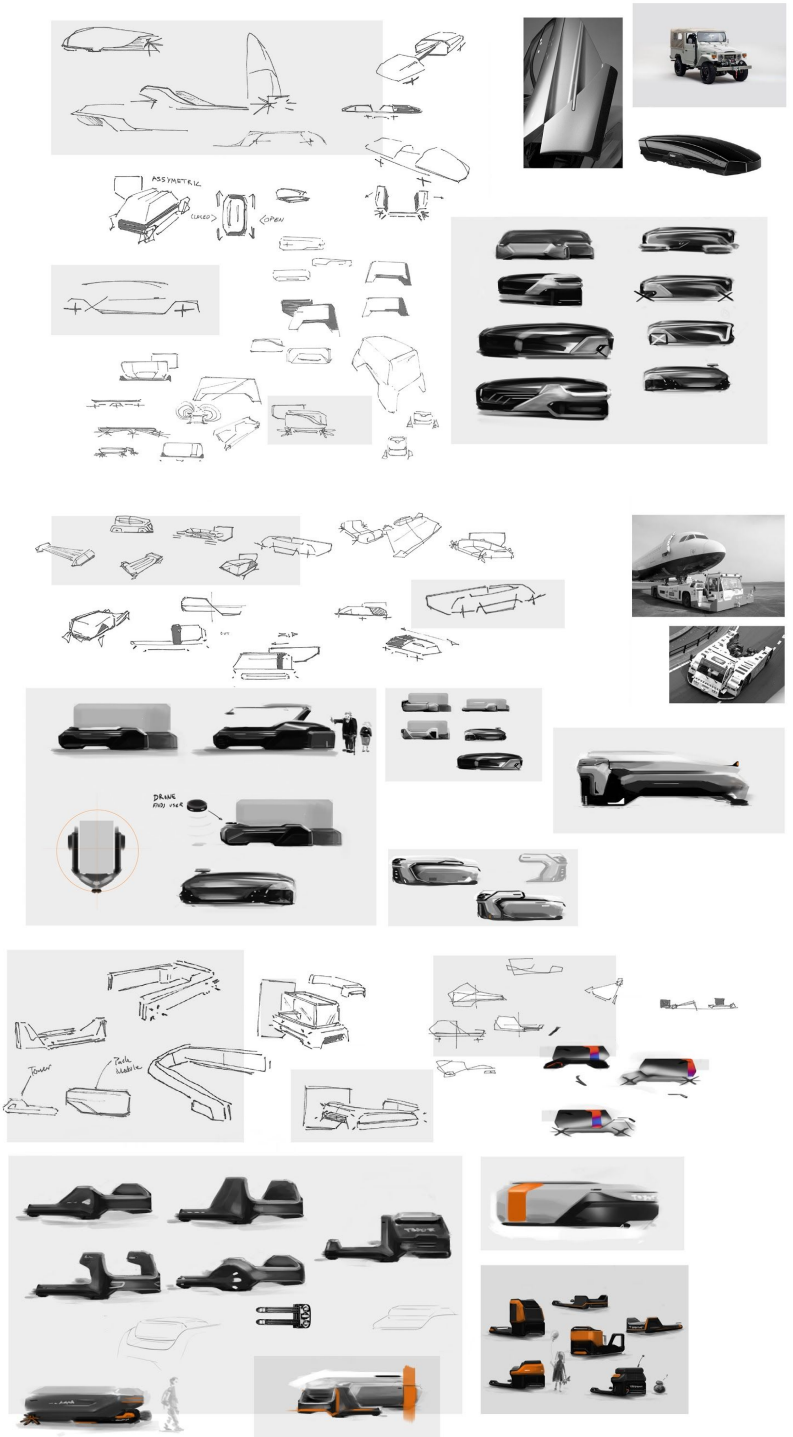


Image 3D Various sketches from digital sessions

Key findings from concept sketches (digital)

During this phase a large amount of concept ideas and directions were generated. Focus on width and diversity in concept ideas and technologies. Ideas were continuously grouped to

allow a number of concept directions to gradually take shape. The images (*image 3D*) show an example from the final grouping of the sketches for further development of concept directions. The final directions will be presented in section *3.1.5 Concept directions.*

3.1.4 Workshop

The workshop provided a chance for discussions about challenges and opportunities related to the scenario and context for the project (*image 3E*).

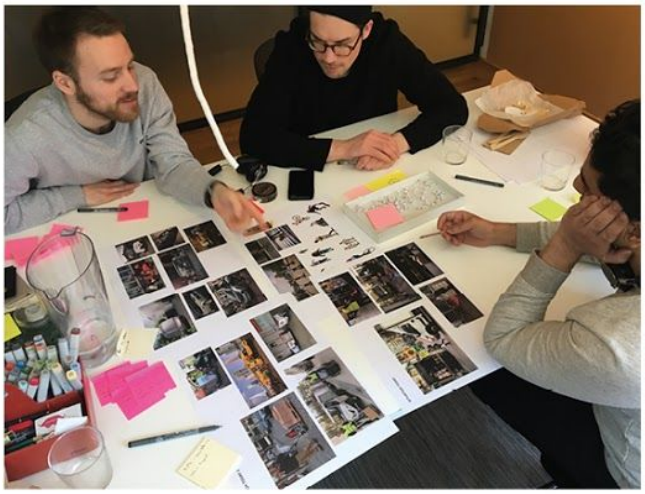


Image 3E Camera shots from workshop session

Key findings from workshop

The workshop acted as a confirmation of insights and ideas gained in the project. The discussion were highlighting a number of contextual factors to consider in relation to the initial ideas gained from previous ideation phases, such as the dominance and hierarchy between vehicles and pedestrians in an urban context, alternative functions with the concept and how different solutions could be affected by preconceptions etcetera. Discussion about pros and cons with ideas provided useful insights that was brought into defining the final directions.

3.1.5 Concept directions

From the extensive ideation, a final number of five directions were defined (*image 3F*). These directions together highlights the most interesting outcome of the ideation and challenges different aspects of the design brief. The five directions are introduced below, together with a SWOT-analysis for each of the directions.

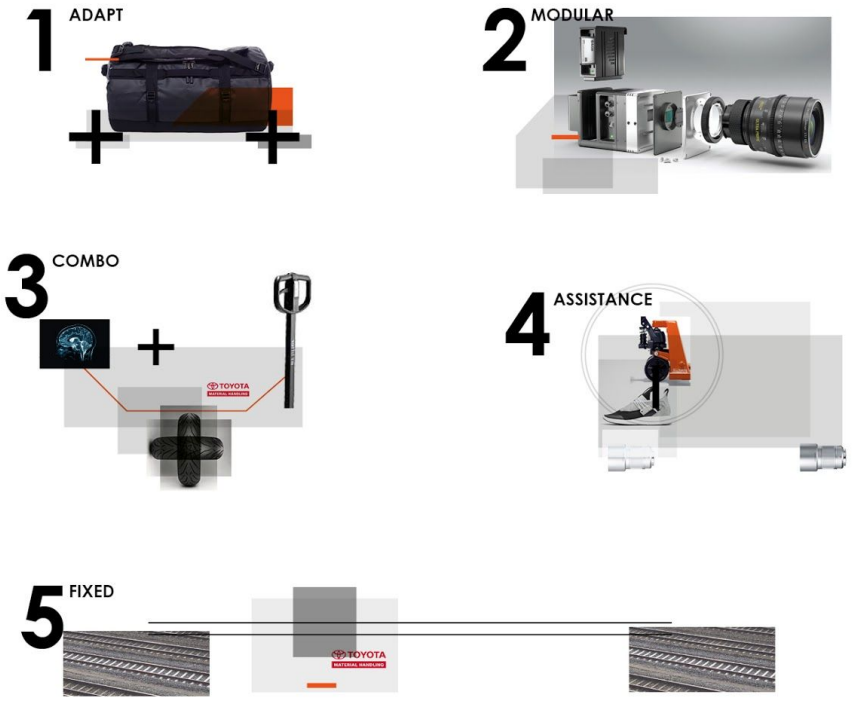


Image 3F The five concept directions illustrated

1 'Adapt' Follow unit that allow user to carry a larger load are designed to be integrated with systems for human mobility. The product is accessed where user pick up pod/bike-unit for human mobility, and is digitally connected to the human vehicle. The product physically adapts to current condition, used or passive mode . By physical flexibility, the product can handle a variety of load volume, and minimizes occupation of physical space and experienced volume and dominance in context, both when empty and used.

S	*Minimize (physical and experienced) negative impact on context*
W	*Concept depend on external OEM products*
O	*Clear differentiation from human mobility (Toyota Cars)*
T	*Regulation, Feedback*

2 'Modular' The volume and handling function is separated into individual products. The volume is delivered to user, while an autonomous handling unit moves on to perform other tasks. When user have loaded the object, the handling unit is called for pickup to transport the order to destination. By separating the products, the a system can be created, in which one volume may be moved by a number of connected products. The transport move on grids based on land and water to minimize movement close to humans, and is seamlessly connected to distance transport to extend transport reach beyond city borders.

S	*Maximize use of available products, integration of systems*
W	*Large number of empty journeys*
O	*Potential to expand/standardize*
T	*Require large scale implementation*

3 ‘Combo’ The direction emphasise the combination of shared control of the vehicle between artificial and human intelligence. The product focus on contribute physical strength, while the human mind is responsible for certain decisions. The product allow mobility of both object and user within one product. The user pick up the product from physical centers available all over the city. The product is light and narrow to suit an infrastructure of small pods and bikes. The human appearance may also provide strong benefits for communicative purposes towards the context and tertiary users.

S	*Purposeful use of human intellegence. Independent solution for small or large scale implementation.*
W	*Interfere with human mobility systems. Does not solve issues with empty journeys.*
O	*Technology available*
T	

4 ‘Assistance’ The direction focus on providing user with full assistance in handling the object until final position. When arriving, a small and flexible unit of the product can move inside the building to assist user in handling the object the full distance. The larger unit provide protection and distance for transport on roads.

S	*Full service, benefits for users*
W	*Product complexity*
O	*Expertise within the company (TICO)*
T	*Buildings addressing this issue in the future?*

5 ‘Fixed’ A fixed grid network is integrated in the city, which allow mobility with high efficiency, separated from city dwellers. The system is accessed by user at any part along the dense grid which can then perform a fast and safe transport with minimal impact on the city.

S	*Efficient and high capacity*
W	*Limitations in flexibility and reach*
O	*Extensive presence for TMHE in urban context*
T	*Require city standard*

3.1.6 Selected direction

The choice for the final direction was made based on the pros and cons identified from the *SWOT*-analysis of the concept directions in addition to discussions with designers from TMHE. The directions was discussed in relation to the *concept requirements* and the vision created by the author as part of the research phase. A combination of one primary direction with specific additions was found to meet the main criterias of the scenario in a way that had a relation to the existing product range of TMHE. The selected direction also introduced an idea that were highly differentiated from other concept by TMHE or others. This aspect of uniqueness, as pointed out during discussions with the company, provided a key argument for the decision.

The selected direction to finalize is an autonomous version of ‘Adapt’, in combination with ability for user to control specific features, inspired by the concept ‘Combo’. Below is a number of key sketches selected to visualize the direction (*image 3G*).

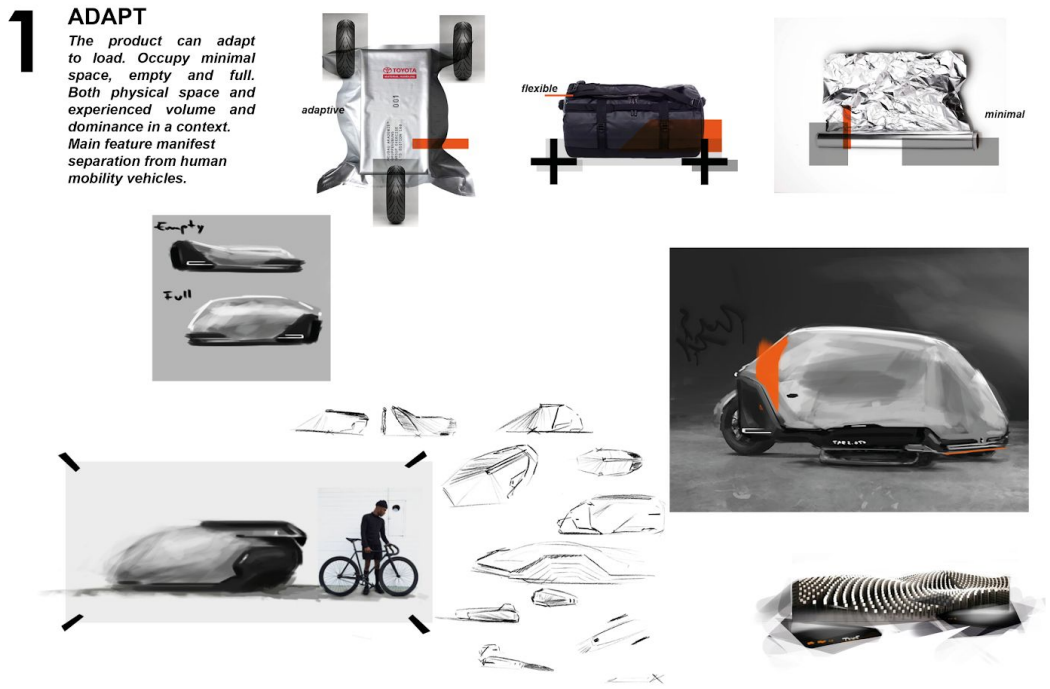


Image 3G Key sketches selected to represent concept direction

The concept consists of an autonomous vehicle that can physically adapt to an empty and loaded condition to fit urban contextual requirements. The product is accessed digitally to schedule order of transport from A to B. On arrival, user can take control of certain aspects of the product, to optimize convenience during use. When loaded, the product handle objects during transport in urban environment. When completed, the product moves on to next task to maximize beneficial use of products within the city.

3.1.7 Additional insight

During the ideation phase, an additional insight was found emerging as a consequence of mobility systems. A product is one thing when viewed as a object. Though when used as a service, the product should acknowledge effects not only as individual product, but as a collective and how this relates to the context.

Technology have a tendency to create monotony when used to create systems, which is not a problem within closed contexts. Though when entering a public context, these effects have to be considered. A system of multiple products within a defined area as a city, the products will contribute and affect the cityscape. In a future of mobility systems, vehicles have to be designed as individuals but also acknowledge collective consequences. This was selected to be a key aspect for the final concept, which will explore an alternative approach of vehicles design which consider both the individual product and the system created in a future of shared mobility.

3.2 Conclusion *Explore*

This phase results in a defined direction for the final concept, with highlighted key aspects . A visual summary of the final direction was created as a summary of the result obtained from the *explore* phase. This will act as the design brief for the final design phase.

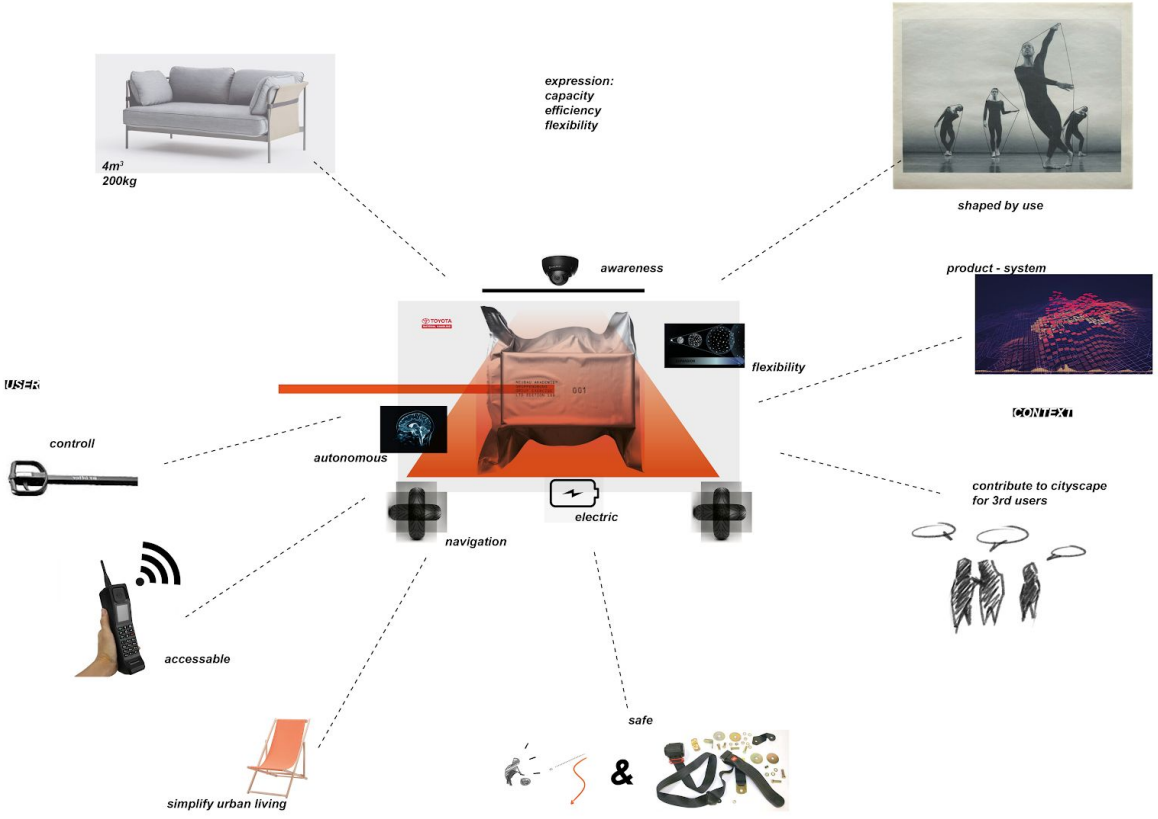


Image 3H Illustration of focus for final direction

IV. Define

Based on the final concept direction and key aspects defined in the previous chapter, this chapter describes the form development of the final concept.

Objective *Define*

This part aims to refine the final direction obtained from the previous part, into a final design concept that embody the key insights into a feasible concept. The final design aim to be an inspiring concept that interpret the Toyota form language in a product that challenge and inspire the definition of a future TMHE product. The final concept will be part of a system, yet the focus of the conceptualization lies on the physical product.

Methods and approach *Define*

Based on the final direction identified in the *explore* phase, the *define* phase started with additional research to verify technological aspects related to the concept. Insights from this could be used as inspiration in detailed refinement of the concept. To define a vision for form and expression of the final design, boards were created to visualize the direction using visual images and key words. These were used for inspirational purpose and as point of reference to evaluate form proposals during the process.

Form development loops were used as an iterative process inspired by the *typological* and *morphological* levels of the *fishtrap model (Muller, 2001)* which focus on creating a number of alterations of each aspect of the design. The process was based on several loops between sketches and polygon based 3D modelling. Each loop focused on exploring variations of a specific feature or expression, from which a number of alternative was created. The alternatives were subjectively evaluated in relation to concept scenario and expression boards. Highly valuable feedback was gained from creative discussions with professional designers during the process towards the final design. This process acknowledge the subjective aspects of design, and relied on subjective decisions based on authors experience and knowledge of the profession of design.

How to read chapter IV *Define*

Chapter IV, *Define*, describes the process of final refinement of the form. The result initially describes additional research and definition of form intentions. This is followed by a section describing key steps during the iterative form development process. The process was a continuous process where the outcome of each loop was used as input for the next. Each image relate to the text above and below and the section should be read in a consecutive order, with the visual images as an essential addition the the text. Methods and approach are described in the beginning for this chapter.

4.1 Result *Define*

Before starting the finalization of the concept with *Form Development Loops*, additional research had to be made to verify the technical aspects. The result could both confirm the level of feasibility in relation to the scenario and vision, as well as providing additional inspiration.

4.1.1 Additional research

Additional and verifying research was conducted regarding technology and material related to key features of the concept, mainly regarding the kinetic solutions for driving, opening/closing and the flexible surfaces.

Soft robotics
Kinetic structures made fully out of non-solid components in an emerging area within robotics (*image 4A)*. Using channels and patterns that are pressurized with liquid or air, the construction are able to walk, lift and move with no solid mechanical parts. (“Multigait soft robot”, 2011)

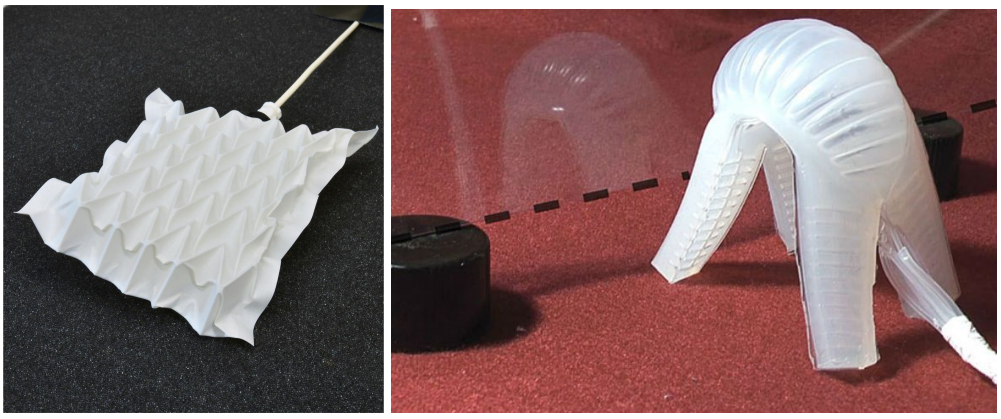


Image 4A Various applications of kinetic structures using soft robotics technology (Whitesides, 2011)(Shuguang, 2017)

Multi directional wheels:
Normal wheels limits a 4-wheeled vehicle to drive only along the primary axis of the vehicle. Two main principles for wheels have been developed to provide 4-wheeled vehicles with the ability to drive along more than one single axis. The mecanum wheel uses a number of rolls mounted on a circular frame (*image 4B*). By alternating the rotation of each wheel individually, the vehicle are able to drive in any direction. (Wikipedia, 2018)

Image 4B Example of mecanum wheel technology (Robu-in, 2018)

Distance interaction:
Depth sensors using multiple cameras to track and assess movement in space have been been available for a long time in products such as *Xbox Kinect*. The technology have been developed to also function in outdoor environment and direct sunlight by filtering out the specific light used to assess distance (Futurity, 2015 K).

Conductive road charging:
The rapid development of electric cars also incorporate technological progress of charging solutions. Wireless charging have been demonstrated for still and moving vehicles The vehicle can pick up charge driving in any direction over the surface, even at higher speeds. (Qualcomm, 2017)

4.1.2 Expression Boards

Key words

A number of three key words were selected to define the expression of the final form. These were further defined with a set of complimentary words.

Approachable - friendly / soft
Reliable - solid / defined
Efficient - flexible / light /precision / pure

The key words were then translated into visual representations to further define the form intention. The expression and mood was done for both the solid and flexible parts of the final form, as well as for details and graphic features. The set of images was acting guiding and as reference point through the whole form development process.

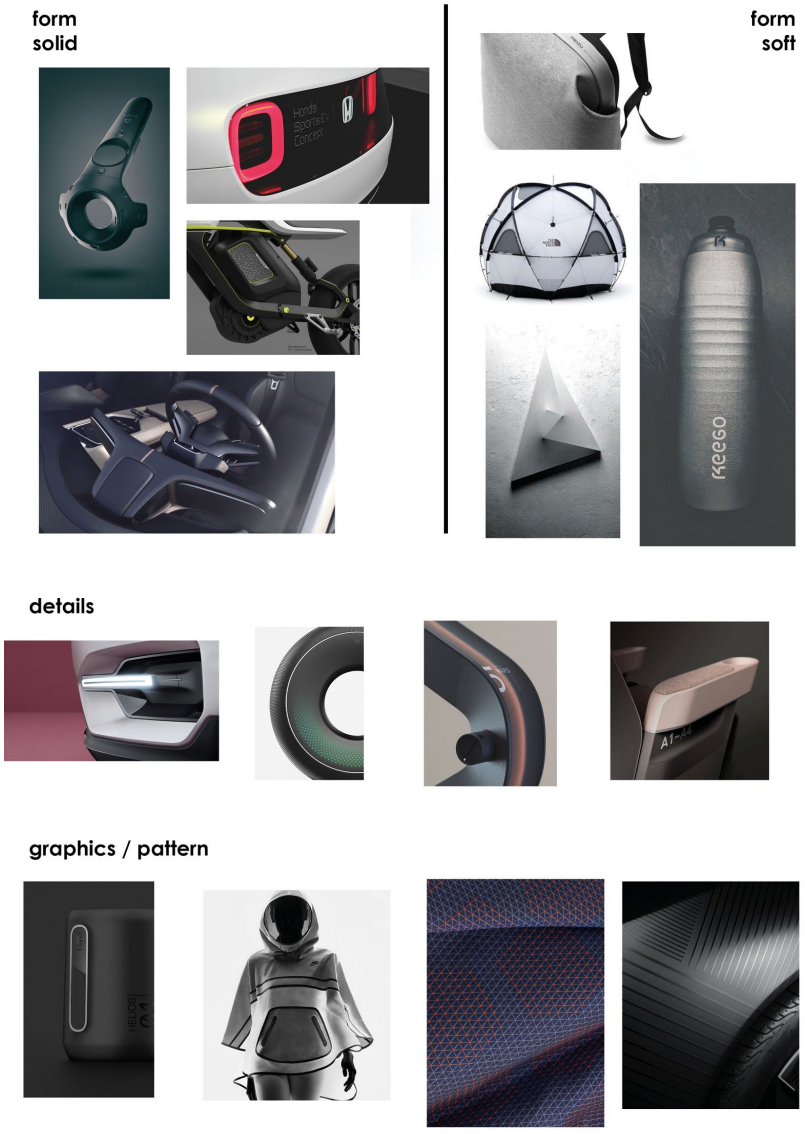


Image 4C Images defining the intended form and expression

4.1.3 Form development loops

The result of the *Explore* phase defined a final direction for the concept. From the insights and inspiration from the *Additional research*, a number of sketches was done to further define the final direction in relation to material and technological aspects (*image 4D*). These sketches defined the basics of the concept and functional aspects and the concept was brought into the final part of form development loops as an iterative process to develop the final form.

Image 4D Key sketches of the early form development process

The concept was made symmetrical along the primary direction of driving. An asymmetrical *arm* hold the *roof box* that would be used to suspend the soft surfaces. The wheels (and possible wheelhousing) was identified as a key form element for the concept. The next phase explored alternatives focusing on the wheels (*image 4E*)

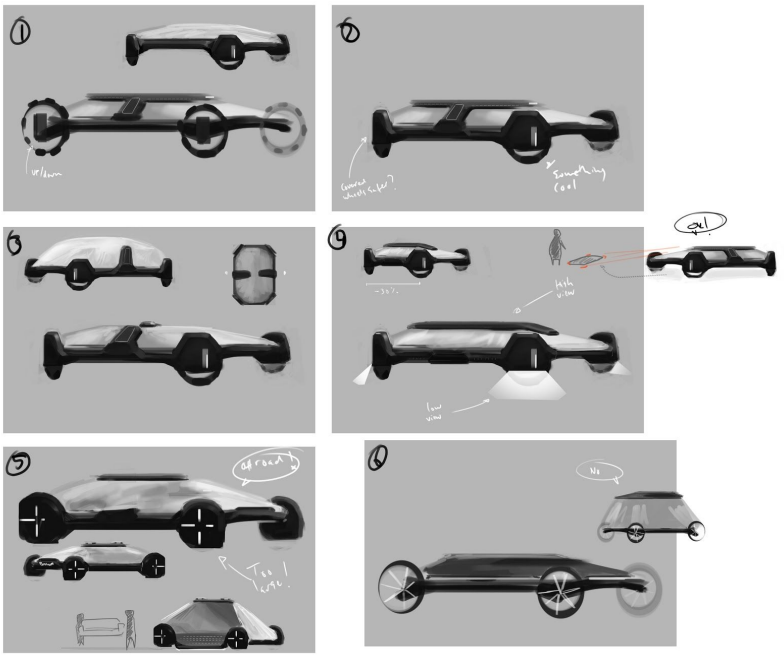


Image 4E

During this process, a number of insights was found. The use of wheelhouse with a defined profile (sketch 2,3 and 4) provided the vehicle with a strong visual identity that also related to a more safe expression. The lightness obtained of the exposed wheel (sketch 1 and 6) was appreciated and brought for further exploration. Also the use of strong graphical features was found to contrast well to the undefined shape of the soft surface.

The *arm* and *roof box* provided a strong visual element to the form, and was furthered explored in relation to the soft surface and wheels in several iterations (*image 4F*).

Image 4F

The *arm* provided several technical issues and was therefore discarded. Instead a direction was proceeded that instead allowed the soft surface to to define the majority of the form on the upper part of the vehicle. Though the strong vertical feature in relation the the

wheelhouses was appreciated and was further explored. The marked sketch selected as the key sketch for further development (*image 4F*). After several loops exploring the vertical element, a decision was made to position it in the front. This gave the the form a direction that corresponded with the function of the vehicle. It was also inspired by form elements and arrangement found in existing products of the TMHE product range. The next loop focused on the basic form of the vertical element, especially in relation the the wheelhouse (*image 4G*).

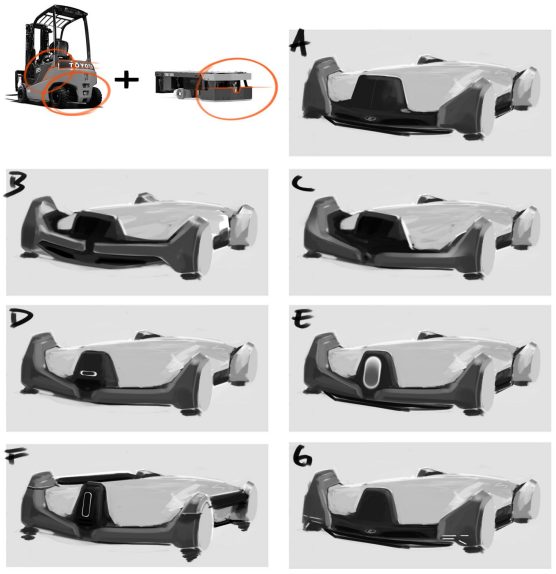


Image 4G

Alternative G (*image 4G*) was selected as the key sketch, with a chamfered outline of the wheelhouse in combination to the more solid form of the surfaces stretching towards the center. This contrast between the solid expression of the surfaces in relation to the light expression obtained from exposing the top of wheelhouse on each side very well combined the use of enclosed wheels with the benefits of the exposed wheel found earlier (*image 4E*). The following loop focus on development of the side of the vehicle (*image 4H*).

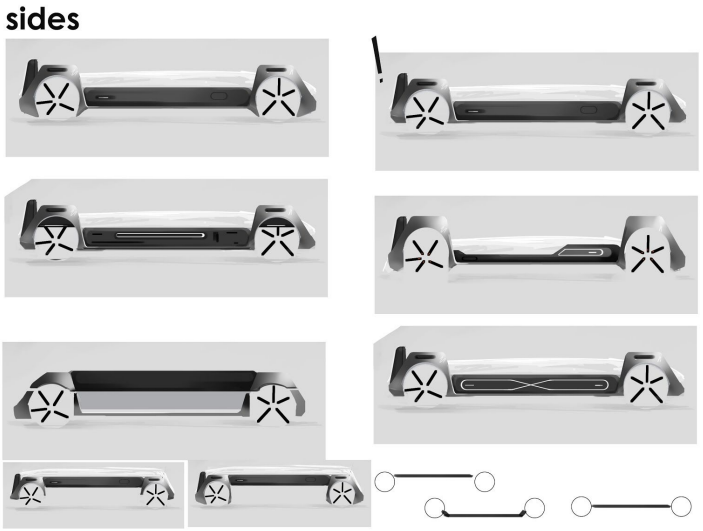


Image 4H

The selected key sketch (marked on *image 4H*) was using a horizontal arrangement of the subdominant featured positioned between the wheelhouse. To increased ground clearance allowed a low center of gravity while avoiding the expression of performance associated with sports vehicles. Next, further development again focusing on improve details of the front of the vehicle, an essential part of the form expression of the vehicles (*image 4I*).

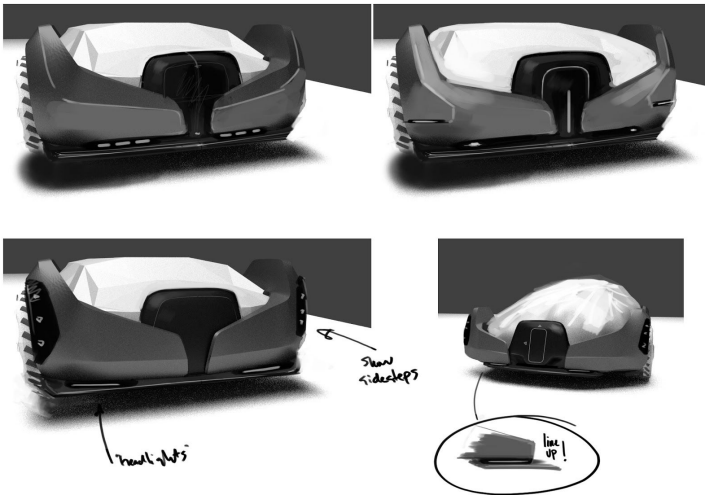


Image 4I

The selected sketch (*image 4I*, bottom- left) used a continuous crease over the whole front. This was made to get a form feature that would work also as the product expanded in width (bottom-right). The expansion was a feature found during the sketch process that allowed the product to occupy minimal space when empty. The next stage focused on development of the wheels (*image 4J*). Early in this process, the asymmetrical use of coloring was identified, which also inspired the coloring of the vehicle. The use of color was inspired by existing products in the TMHE range, and provided an efficient way of highlighting important form features. The coloring also provided a strong visual direction of the vehicle despite allowing the overall form to be symmetrical. The form of the wheels are highly related to functional requirements, thought these was also found to be beneficial for the form. The solid covers gave a solid and durable expression, yet needed more lightness. With several thin lines in circular arrangement, inspired by bike and motorcycle rims, a graphic element was added that also provided more lightness.

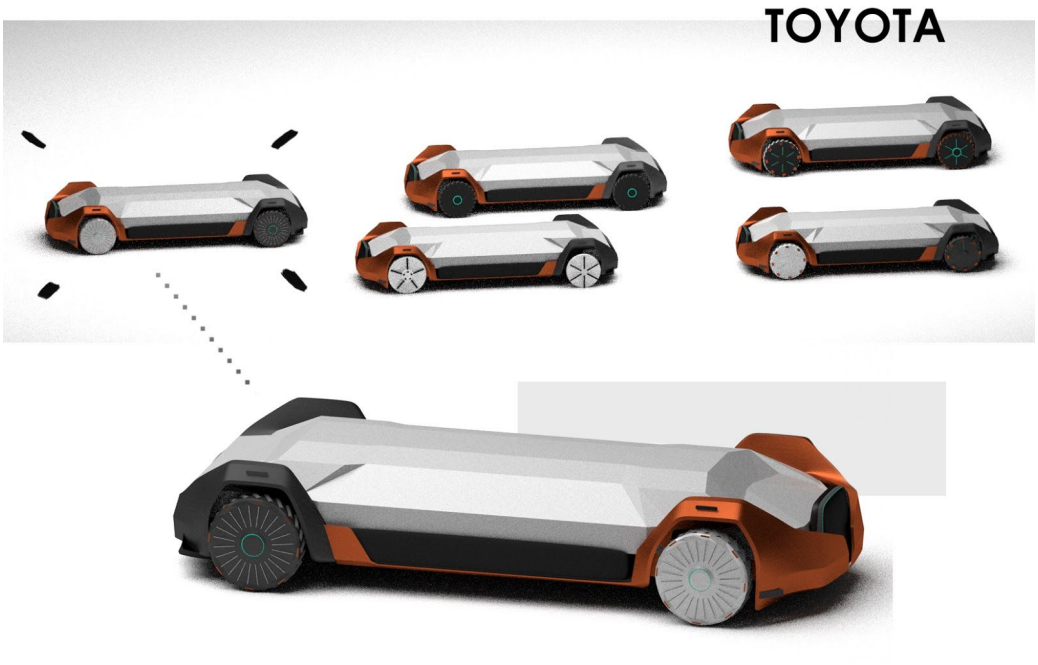


Image 4J

Finally, the graphics of the soft surface was explored. Several experiments were exploring alternatives of several separate surfaces. Ideas providing interesting visual elements was found, yet would not meet the functional aspects of the concept. Instead a single surface was selected (*image 4K*), inspired by the technology of soft robotics found in the additional research.

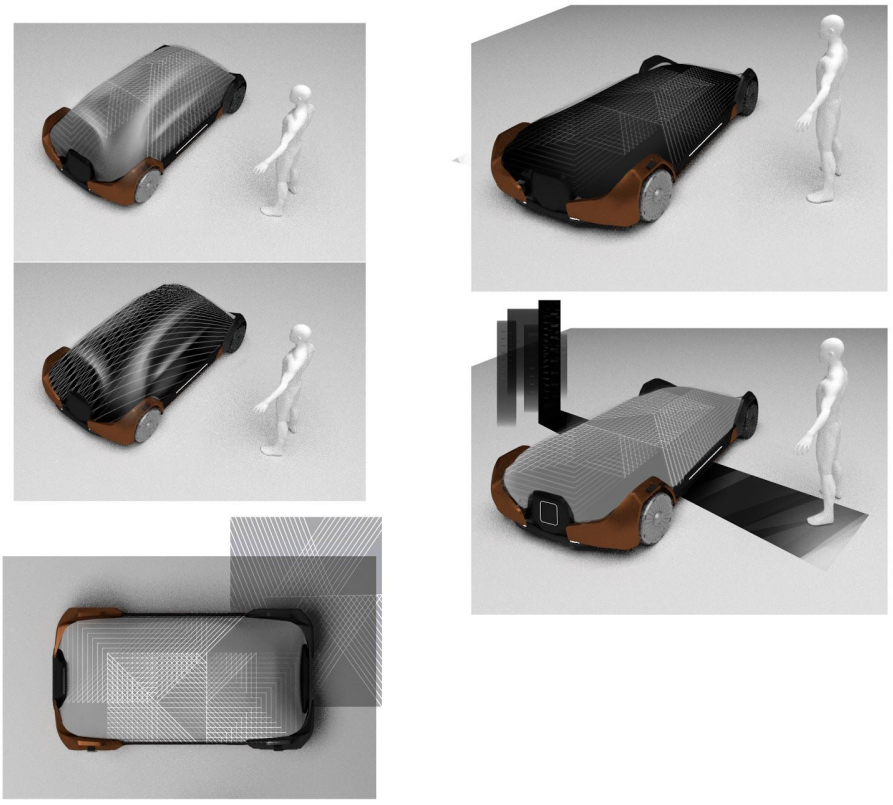


Image 4K

Inspired by the exterior, the pattern for the interior surface was defined (*image 4L*).

Image 4L

An irregular linework (sketch II, *image 4L*) was selected. This related to the exterior pattern, acting as a representation of imaginary shadows casted by the exterior surface. Interior lights was placed on the back of each wheelhouse to light the interior space when loading the product.

4.2 Conclusion *Define*

The outcome is a final concept design of a product for an alternative future of Toyota Material Handling. The concept shows a feasible form that integrates future technology to inspire and challenge the definition of a product of Toyota Material Handling. The next chapter is dedicated to a presentation of the final concept.

V. Final result

The fifth chapter present the final design and highlight key features of the final concept of this project.

5.1 Final Concept

The final concept is an autonomous vehicle that enable object mobility within urban environments. By an adaptive scaling of the product, it can efficiently navigate within the city. On arrival the product expands and positions according to users command by intuitive interaction. The product is convenient to load and provide large capacity. When loaded, the product safely handled the cargo during the transport to final destination at desired arrival time.

The exterior is shaped by how each product is used, highlighting the purpose of the vehicle and creates a natural variation of the system as multiple vehicles are used across the city. Each product is build identical by toyota to minimize costs, still the system as a whole contributes with variation and dynamics to the cityscape.

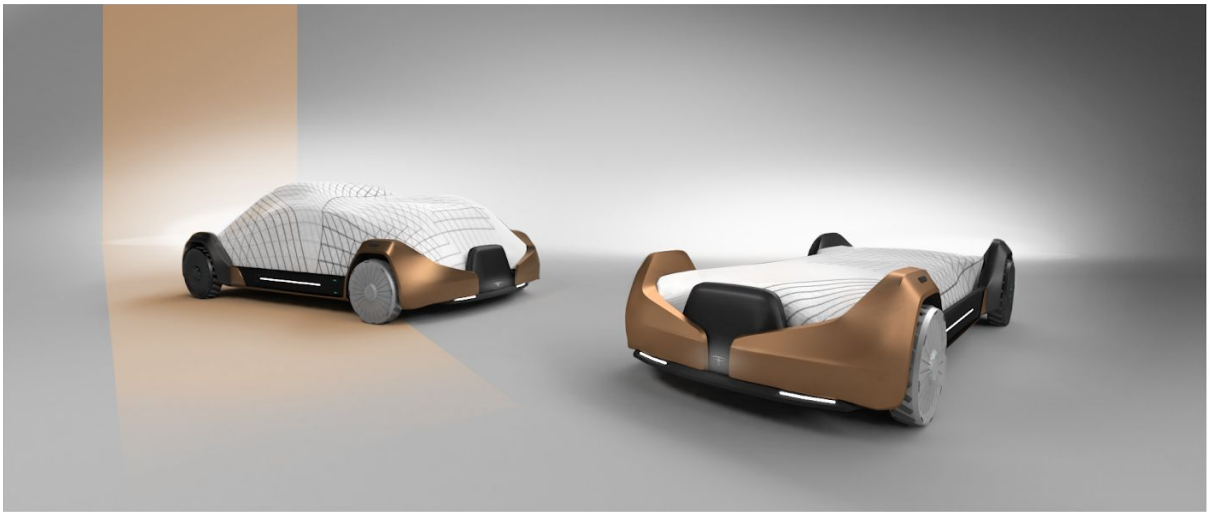


Image 5A

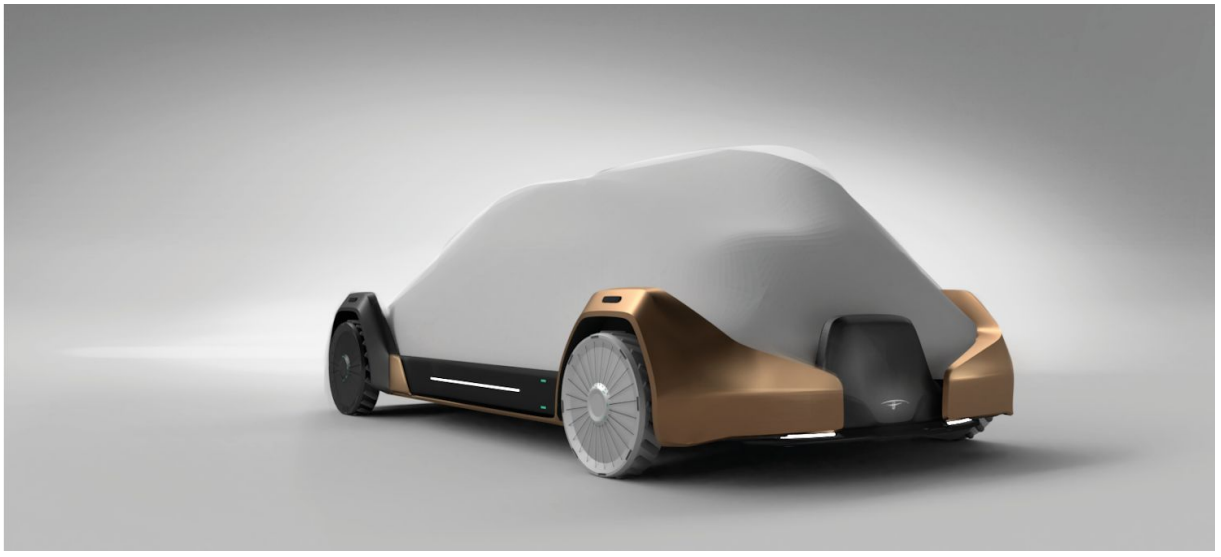


Image 5B

Packaging and adaptive size

The size of the product is defined by the objects it carries. To do this, it has two modes (*image 5C*). The vehicle can expand in width to take up minimal ground space when empty, yet provide high capacity when needed during the actual transport of objects. The narrow mode is called *Efficiency mode* and the extended is called *Capacity mode*, as shown in image below. When empty the product is in *Efficiency mode*, referring to efficient move in the city towards next task. When used, the product changes to *Capacity mode*, to provide large space for users to fit their objects. Still the product maintain a total size which fit in the urban context.

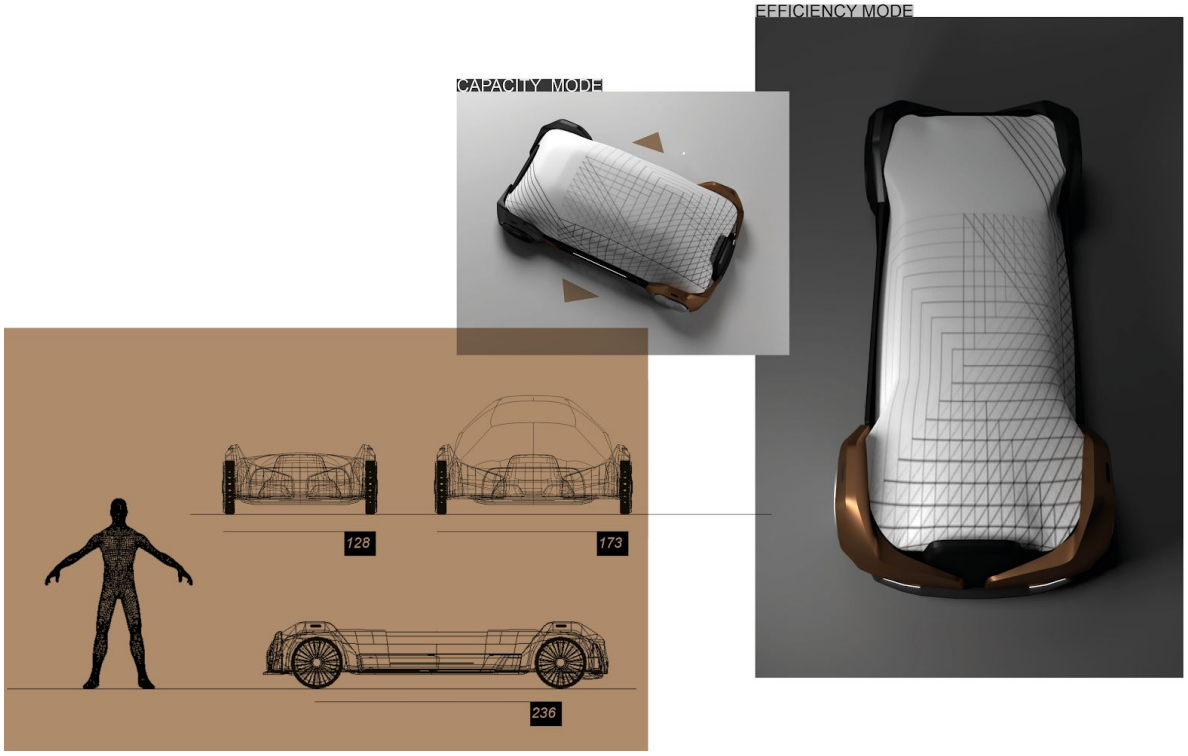


Image 5C

The platform

The interior consists of a platform that provide a large surface for loading objects (*image 5D). T*he width of the platform is expanded by adding a section, inspired by the extension of a regular dinner table.

Image 5D

The flexible cover
The platform is covered by a flexible surface that protects from external damage and holds the cargo in place during transport. When it is time to load, the product open up on each side. The opening sequence starts with folding down the side-panel which seals the opening. After that the flexible cover is raised. This gives user access from both sides while interior lights provide visibility inside.

The construction that raises the cover is integrated in the material. By applying air pressure to the integrated channels, the surface can be controlled (*image 5E*) by a solution that is lightweight and space efficient when not used. When the product closes the surface will wrap around the objects loaded and grab hold of the cargo during transport without the risk of damaging or scratching.

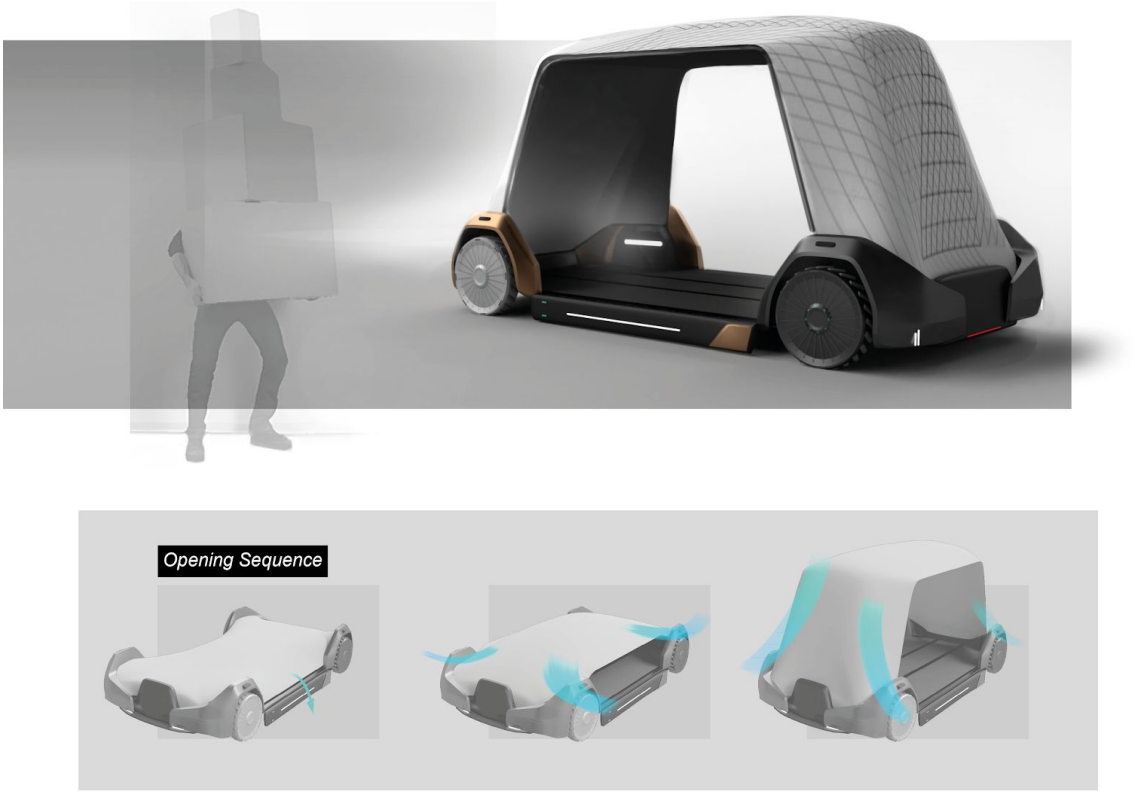


Image 5E

Efficiency mode

The *Vision 2035* describes an expansion in infrastructure for small urban bikes and pod vehicles. The narrow width allow the product in *efficiency mode* to move freely on all roads available in the city to get to the destination as easy as possible (*image 5F)*. The vehicle moves at a max speed of 25 km/h to match traffic.

Image 5F

Capacity mode

When the cargo is loaded, the autonomous product take care of the transport (*image 5G)*. The increase in size is unavoidable, so in capacity mode it selects appropriate routes. In 2035, there will still be regular roads for normal traffic, commuting, logistics and service vehicles. The cargo is secured and held in placed by distributed force from the flexible cover.

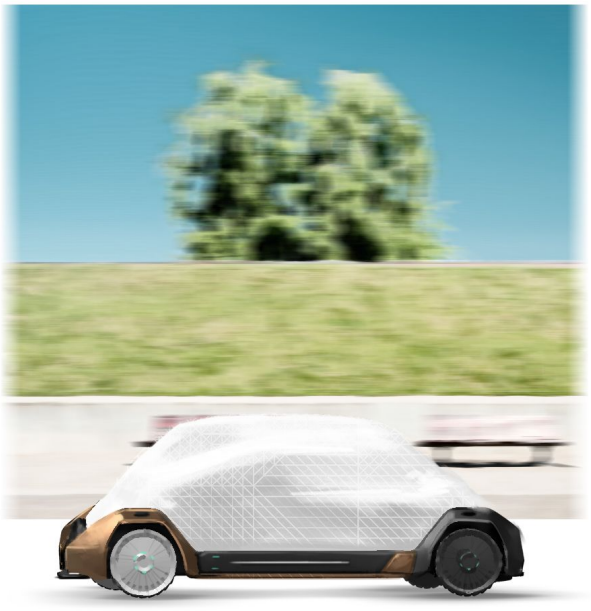


Image 5G

Interaction

User can intuitively control the vehicle by gestures, inspired by the interplay between a person directing a driver parking a car or a marshall directing airplanes on the ground (*image 5H*). By sensors positioned above each wheel of the vehicle and the four mecanum wheels allow the product to “drift” in any direction across the surface, freely move in any direction on a horizontal area. The autonomous vehicle can follow gesture commands by the user for positioning to allow convenient loading and avoid positioning that interfere with other users or traffic. To communicate direction and intention, the product projects a light pattern on the ground (*image 5I*). This enables the people all around the product to be aware of the intended direction of the vehicle.

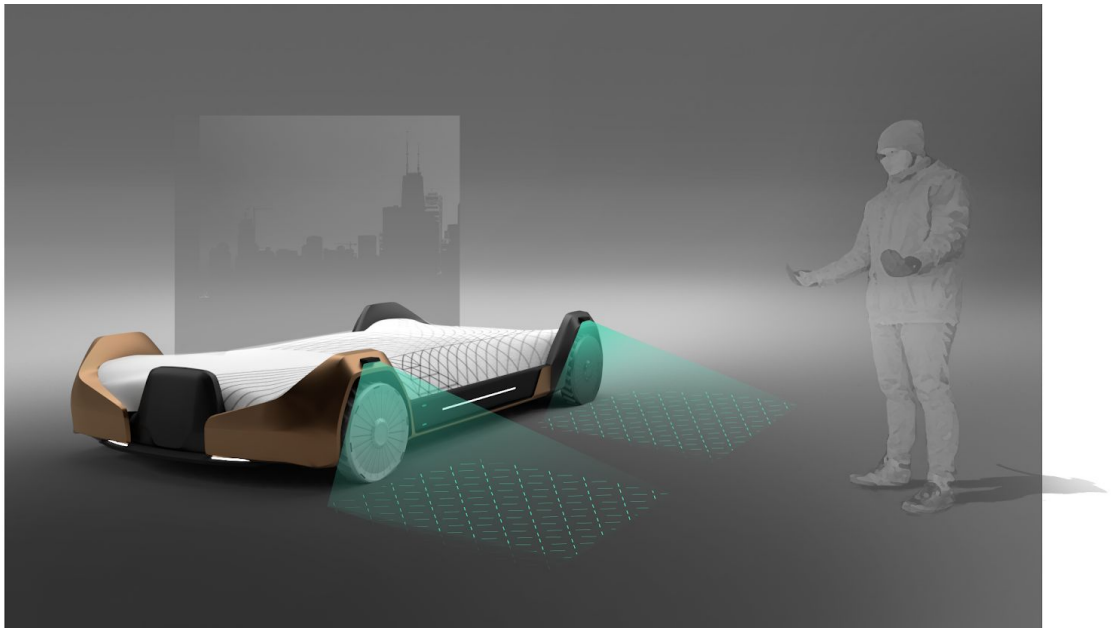


Image 5H

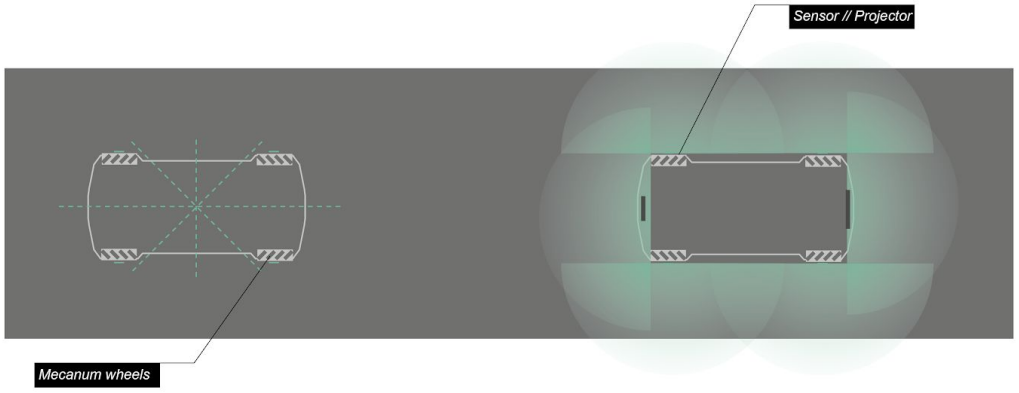


Image 5I

Charging

Instead of allocating precious space for charging stations in the dense city centers, or force products to drive detours just to charge, a grid of wireless charging areas are placed at key passes over the city (*image 5J*). This way each product can be used as much as possible, and charge in the meantime.

Image 5J

Form and Color

The stance and proportions aim to express stability and reliability, and contrast with the flexible surface by simple and well defined forms. The overall form is symmetrical, with details and especially coloring provide a direction, with lighter colors towards the front, and darker in the back (*image 5K*).

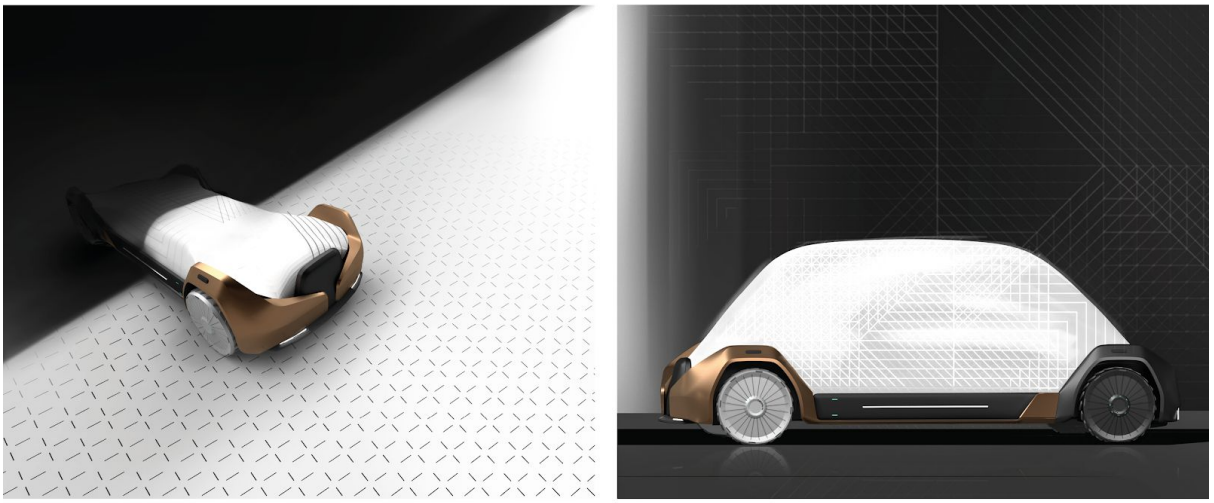


Image 5K

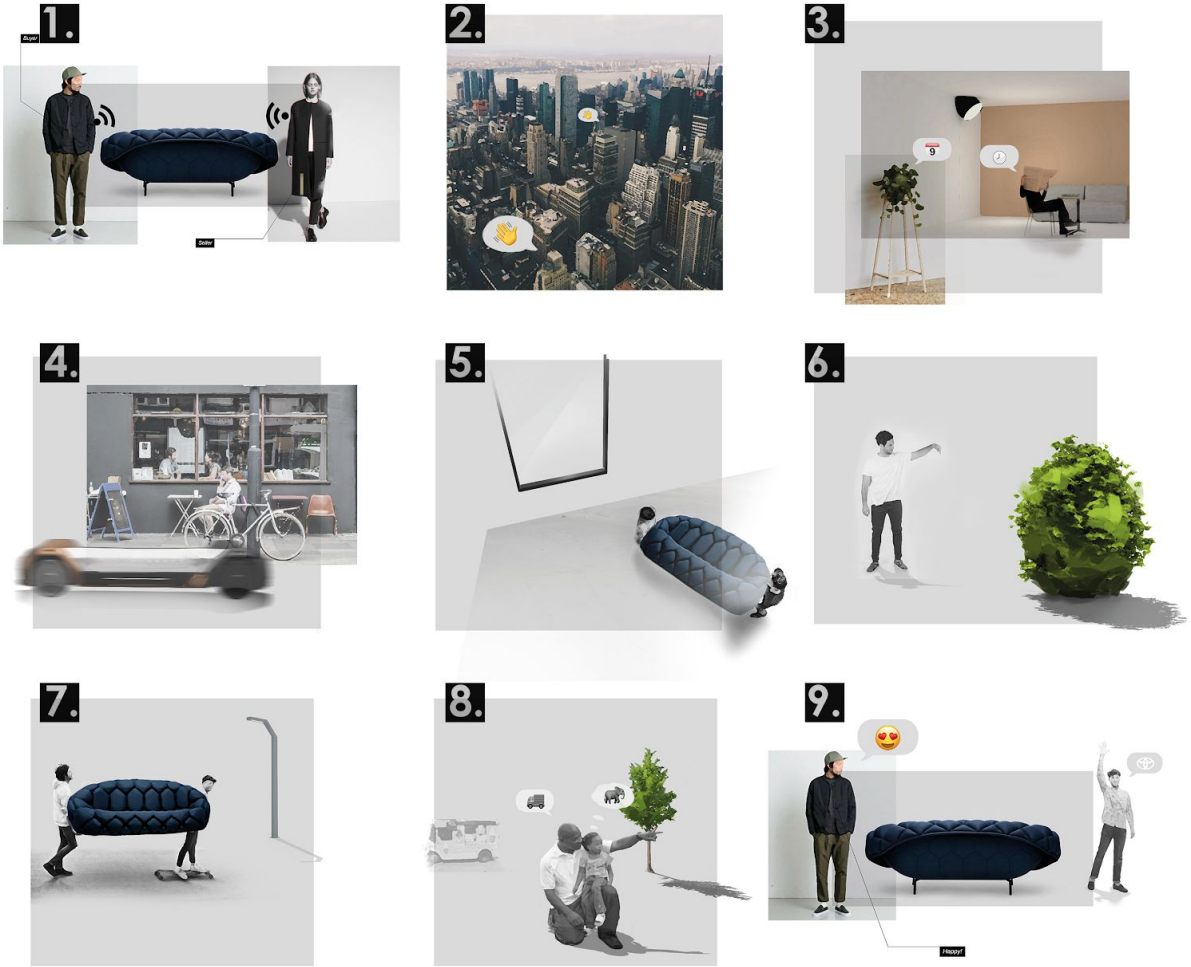
The surfacing around the wheelhouses provide a solid expression, yet the exposed top gives a certain lightness. The relation between the centerpiece and the wheelhouses is very inspired by the carrying - carried relation found in many tmhe products, but much more hollow to be light and efficient. A design that works in two modes implied a major challenge for the form. This was solved by splitting the front in two halves that can be separated. The

form consists of several pieces that works as a visual puzzle. When the product expands, new features are revealed, that ties the form together.

The final colors interprets the conventional color scheme of TMHE products with lower saturation to suit the urban context. An accent color have been used at minor details to add character and an approachable expression.

5.2 Story

The final concept was presented as a story, to highlight the effects of the concept from a user perspective.



1. Through a digital platform, our user finally find someone selling the exact sofa he look for. It's a deal! On the digital platform the two can easily access the integrated delivery service provided.
2. They both live in the city center, within a few km from each other.
3. With the help of some of your smart home technology, users just arrange the pickup and dropoff when it suits them.
4. The transport is on its way. When empty, It moves with ease through the city with minimal negative impact for the citizens.
5. In the meantime the user can focus on getting the product ready.
6. When the transport arrives, the user can take control of the autonomous vehicle and position it for convenient loading.
7. The sofa is loaded and the transport is sent of for the destination.
8. Multiple vehicles are constantly moving around the city, taking care of transports while people are instead spending time on purposeful things. The flow of products even contributes in being a dynamic part of the cityscape in addition to nature and architecture.

9. The sofa arrives, and task is completed. Everyone is happy! Meanwhile the vehicle instantly moves on to the next task, helping a young student moving this time.

VI. Discussion and Concluding remarks

The final chapter discuss the project, process and result and present final concluding remarks by the author.

6.1 Discussion

6.1.1 Process and Method

Methods
This project was executed as a concept study, driven by an explorative and subjective approach. The focus of the study is based on a vision of the future. The scenario provide relevant estimations and insights, but can not be viewed as certain predictions. These are a result of the subjective analysis of the author. If the same project had been carried out by another individual, a different result is likely to be expected.

Open brief
This project was initiated with an open brief, which allowed an explorative process. Much of the findings and insights during the project are not directly relevant to the final concept and thereby excluded from this report. A project initiated with a more narrow scope could possibly have resulted in more result directly related to the final outcome and a more streamlined process. Though an initial brief would then have to be based on assumptions to a larger extent than for a brief that continually refined during the project.

Subjectivity in process and decisions
The subjective opinions of the author have been central for the project process. As a consequence of working in the context of a future scenario, many of the decisions taken in the design process are made subjectively. This may affect the final result of the project.

Evaluation
A concept study can not be evaluated by a group of users or a contextual factors. Though the purpose for this project is not to identify the optimal solution, but to present the concept as a visual representation of ideas and thoughts that can act as inspirational alternative for future development.

6.1.2 Result, insights and challenges

The purpose of this project was achieved by the explorative process that continually narrowed down the focus of the final concept. Starting from an analysis and definition of the company, each step provided input used in the following step to assure the final concept has a relation and relevance to Toyota Material Handling.

The first aim of identify a future application was achieved by research and analysis of the company, the industry and the society, resulting in a future vision and user scenario. Within this a future need could be identified that corresponded to the expertise and business of TMHE. By an sketch driven design process, a final concept could be defined that fulfills the second aim of defining a concept that elaborate on an alternative direction of TMHE product to meet challenges of the future.

Logistics role in society
The final result is a concept that challenge TMHE´s and others definition of urban object mobility and logistics role in society. The research identified this as a possible scenario based on the benefits and requirements from a user perspective. Though this is also an evolution driven by the industry. The project visualize how the expertise and technology of TMHE could be applied in order to take an active part in rewriting the definition of logistics role in society.

Mobility as systems
The concept acknowledge the consequences of how vehicles contribute as individual objects as well as a system as a whole. The effects of repetition and its consequences has a major effect on the context and cityscape. By allowing the use of the product affect the expression, the function is enhanced at the same time as the system gets a natural variation. This benefits both functional aspects as well as the experience.

This insight have not been elaborated in previous concepts known to the author. The same effect is today a consequence for TMHE products, which most often are working in systems of several products. If the future direction of the company implies a more present role in an open context, this aspect is by the author regarded as single most relevant insight to consider. As the vision also suggest, this aspect might even evolve to be an external requirement from the city or expectancy from users.

6.1.3 Further development

A future concept will constantly be developed and refined until the concept eventually reaches a production phase. A concept study to explore the future direction of a company should be viewed as a part of an ongoing process. The project result should be viewed as a contribution to an ongoing exploration of the future. As reality gets closer to the concept vision, additional insights from users and context can be obtained that should be considered for the concept.

Additional aspects not included in this project needs to be further developed. The concept proposed will be used as part of a service. This project was initiated with focus on the physical product, though designing the service and user touchpoints would be required in further development of this concept.

Also the financial perspective of the concept have not been elaborated in this concept study. Research regarding technology and material is conducted on a conceptual level to reflect the time perspective of the concept. Elaborated research is required to verify technical aspects of the concept and implementation in production process.

6.2 Final concluding remarks

The master thesis project results in a concept that interpret Toyota Material Handling within a context not previously explored by the company. The concept visualize how technological progress can inspire to new products which explores an alternative future definition of the company. The vision in which the concept is created, highlight a number of aspects relevant for Toyota Material Handling to meet the future challenges and opportunities of material handling operations in urban areas.

The report provides an holistic overview of the process during this concept study. The insights from this project can be used as inspiration and initiation of discussions related to the future of mobility for humans and objects and the role of logistics in urban areas.

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